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THE X-33 AND THE X-38 EXPERIMENTAL AIRCRAFT:
ENVIRONMENTAL CONNECTIONS WITH AEROSPACE SCIENCE

A Project
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Education:
Environmental Education

by
Elandriel Jean Martin
June 2001


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ABSTRACT

The curriculum, The X-33 and The X-38 Experimental Aircraft: Environmental Connections with Aerospace Science, was designed as the basis for the combination of basic environmental science concepts with aerospace science for fourth grade classes. The lessons were designed to aid students in exploring the history and science of their local area, the Antelope Valley, via the use of aerospace technology currently undergoing design and testing in that area. This exploration fosters in students a sense of place and connection with their home area. It also provides students a real-world basis upon which to study the concepts of weather and geography. This curriculum can be used, with little alteration, anywhere that the X-33 or the X-38 are flight tested.

ACKNOWLEDGEMENTS

A work of this magnitude is never accomplished by one person alone. I would like to thank the following people, in no particular order, for their help and support: Darleen Stoner, Ph.D. for her guidance and support, Wayne Ottinger and the office staff at P.A.T. Projects for assistance with background information and graphics, and Kathy Johnston for her help on revisions and information on standards.

To Kira,
Kathy,
and the Hamil-whea-mar clan.
I couldn't have done it without your support and
encouragement.

Also,
to the pilots, engineers, and crews
who continue to challenge us to reach beyond
the boundaries of our imaginations.

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CHAPTER ONE

INTRODUCTION

The National Aeronautics and Space Administration (NASA) has long been a strong presence in the field of education. Prior to 1995, most of the educational resources produced by NASA were developed and written solely by NASA engineers. While the science behind these resources was of the highest quality, often they were written above the level of the lay person. Many teachers, particularly those at the lower grade levels, found these resources difficult to implement in the classroom.

In an effort to increase the understanding and the usage in the classroom of their resources, NASA embarked on a new educational program in 1995. This new program paired educators with NASA engineers. The NASA engineers were to provide the background history, math, and science for a resource. The educators would then translate that knowledge into useful and easy to understand lessons for the classroom.

The new program then went a step further. In the past, most of NASA's educational resources addressed broad topics, such as general aeronautics. The resources produced by this new venture were to be much more specific, relating current and local NASA space and flight projects to the classrooms that are local to the areas in which these projects are being tested and used.

In the Antelope Valley of California this new program was realized in the form of a partnership between the NASA/Dryden Flight Research Center (DFRC) and Preservation of Aerospace Technology (PAT) Projects. The NASA/DFRC is located at Edwards Air Force Base, the premier flight test facility in the United States, if not the world. P.A.T. Projects is a non-profit organization that works in association with the Society for Experimental Test Pilots branch in Lancaster, CA. Dryden provided the representative engineers from current NASA programs to work with educators from across the Antelope Valley employed by P.A.T. Projects. These educators are of varied grade level, subject area expertise, and experience.

The Antelope Valley has a rich aerospace history. For many years it has been host to the site of such technological breakthroughs as Chuck Yeager's landmark breaking of the sound barrier. Many astronauts have been trained in the area, and the Space Shuttle lands there. When asked, students in this area are often unaware of the rich history that surrounds them. Thus P.A.T. Projects entered into this venture with the goal of developing curriculum on local aerospace history and technology for kindergarten through grade twelve for local classrooms.

The result of P.A.T. Projects' efforts has been several units that were constructivist in nature and coordinated with the national standards in science, math, history, and geography. These units were in grade level groupings of kindergarten through grade four, fifth through eighth

grade, and ninth through twelfth grade. Some of the aircraft used as a focus for these units were the Pathfinder, a solar-powered high-altitude flying wing; the X-33, the prototype for the new space shuttle; and the X-38, the Crew Return Vehicle for the International Space Station.

In order to further the goal of bringing local science and history into local schools, this master's project has coordinated the aforementioned aircraft with several important concepts in environmental education, thus allowing for infusion of these environmental concepts into the curriculum. The environmental concepts range from weather and atmosphere studies to geography and mapping. Thus, this project provides local students and teachers with exciting and informative curriculum that encourages learning through hands-on activities that focus on the relationship of aerospace sciences to the natural world.

CHAPTER TWO

LITERATURE REVIEW

The year 2000 marked the 30th anniversary of Earth Day in the United States. Launched in 1970 as a response to the growing public awareness of the continuing degradation of the natural environment, Earth Day was just one of many facets of the American environmental movement of the 1960s and 1970s that focused on education. While the environment has been a constant focus in one form or another since the beginning of education in the United States, it was this environmental movement that was largely responsible for bringing the idea of "environmental education" to the forefront of the American public's educational conscience. This literature review discusses the origins and purpose of environmental and constructivist education, as well as their relationship to issues of local science and history. This project addresses these topics through the use of constructivist lessons on that correlate the local science and history of the Antelope Valley with the goals of environmental education.

Due largely to the widespread publication and media attention given to Rachel Carson's landmark book in 1962 on pesticide misuse, *Silent Spring*, the American environmental movement that followed included a broader segment of society than its predecessors. Activist groups and environmental education programs began to appear throughout the country in response to a new awareness of environmental mismanagement

and ecological danger. Due to its large support base, the movement was able to realize the passing of laws and policies that supported environmental education and its goal of producing a citizenry that is "knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve those problems, and motivated to work toward their solution." (Stapp et al., 1969) Two of the most significant were the National Environmental Policy Act of 1969 and the National Environmental Education Act of 1970, "both of which identified education as a mechanism - a tool - for improving the quality of the human environment" (Disinger, 1997, p. 24).

Many of the major accomplishments of the American environmental movement of the 1960s and 1970s continue to be viable in today's society. Scores of educational and activist organizations and programs arose in response to Rachel Carson's call for an "awareness that we are dealing with life -- with living populations and all their pressures and counterpressures, their surges and recessions" (Carson, 1962, p. 296). Many of these have survived, and even grown, into the present, as the resurgence of interest in the environmental movement in the 1990s had the American public once again embracing the ideals of environmentalism. The government once more found widespread public support when it passed the new National Environmental Education Act in 1990 which "reemphasized the need to increase public understanding of the natural environment, and to advance and develop

Environmental Education and training" (Klein & Merritt, 1994, p. 15).

With these increasing public and legislative pressures to incorporate environmental education into the curriculum, educators have often found themselves faced with numerous frustrations. In a study done by Ham and Sewing (1986, p. 17-18), educators indicated that it was a lack of time in the school day, that is a lack of room in an already packed curriculum, as well as lack of time in the school day and lack of training and materials, that was the chief obstacle to teaching environmental education. This is a very valid point as "no one asks the schools to do less, but many special interest groups demand that they do more, curriculum overload is a serious and burgeoning problem in the nation's schools" (Disinger, 1997, p. 39).

The concept of a lack of time in the school day points to a widely held misconception that environmental education is a separate entity from other curricular areas. "Environmental education should be infused at all levels of education, not replacing existing curriculum but rather augmenting it with environmental examples and experiences that can be used to validate the existing courses of study" (Cobb, 1998, p. 6). This is relatively easy to do as the themes of environmental education range from the physical and biological sciences to the social and historical study of moral and ethical responsibility. In fact, it is uncommon to find environmental education addressed as a separate subject

within the U.S. school systems, with the physical and biological sciences being the primary courses selected for infusion.

Not only does infusion of environmental education address the problem of its incorporation into an overburdened curricular system, it also reveals an answer to some of the problems of American science education recently under discussion. The 1989 report, Science for All Americans, by the American Association for the Advancement of Science, "pointed out that American science education typically emphasizes the learning of answers rather than exploring questions, memorization rather than critical thought, and fragmented learning as opposed to understanding in context" (Cobb, 1998, p. 6).

These issues are addressed within the bounds of environmental education as it often focuses on the practical application of ideas within real-world problems. In this way students are often provided not only with the knowledge of the concepts that are desired by the schools, but also with the ability to apply their learning in solid, practical ways. As problems in the real world are never limited to one discipline, environmental education thus provides a way in which to combine disciplines from across the curriculum, from language arts to physics, and from history to biology. Thus, "interdisciplinary and connectedness are the key operative words that distinguish environmental studies from other modes of scientific inquiry" (Cobb, 1998, p. 6). These

interdisciplinary methods of environmental education are often seen as consistent with the ideas of constructivism.

Constructivism is an educational theory that proposes that students learn best by constructing their own body of knowledge from personal experiences. Guided by the teacher, students create their own theories and hypotheses to explain phenomena with which they are confronted. When their theories contradict that which they experience, new theories are created. In this way, the information and knowledge that the student acquires has increased meaning because "knowledge is actively constructed by the cognizing subject, not passively received from the environment" (Lerman, 1989, p. 222). In other words, students assimilate information more readily, and easily, when they understand the importance and usefulness of it.

According to Klein and Merritt (1994, p. 16), a successful constructivist lesson has four main components. To begin with, the teacher presents a real-life problem for the students to resolve. By beginning with a real-life problem, as opposed to a theoretical one, students are provided with a basis in reality with which to compare the importance and usefulness of concepts and ideas to be learned. This aids in the production and retention of knowledge and skills on the part of the student.

Introduction of the problem is followed by student-centered instruction facilitated by the teacher. The teacher takes this time not only to provide background information

about the problem to be studied, but also to assess the prior knowledge of the students, and address any misconceptions held by the students. Addressing student misconceptions is important as "misconceptions do not simply signify a lack of knowledge, factual errors or incorrect definitions. Instead, misconceptions represent explanations of phenomena constructed by a student in response to the student's prior knowledge and experience" (Munson, 1994, p. 30-31). Since the basis of constructivism is to allow students the opportunity to construct their own realities based upon their prior experience, addressing student's misconceptions is a vital process of constructivism in order to ensure that students develop sound knowledge of the solutions of the real-world problems presented.

The third component of a successful constructivist lesson, according to Klein and Merritt (1994, p. 16), is productive group interaction during the learning process. While working with others within a group setting can be a new experience for students and teachers alike, it can be very beneficial for all to bring students and teachers together "in a common enterprise, that of mutual seeking of understanding. Because many minds are grappling with the material at once while working toward a common goal, collaborative learning unleashes a unique intellectual and social synergy" (MacGregor, 1990-1991, p. 1).

Authentic assessment with demonstration of student progress is the final component of a successful

constructivist lesson. Teachers have the opportunity to evaluate students not only on their knowledge acquisition, but also on the practical application of that knowledge. Students are able to take an active role in their evaluation, from choosing products for assessment portfolios to defending their viewpoints and actions to their teacher, thus pairing "the student and teacher as a team that examines the new knowledge and habits of mind" (Klein & Merritt, 1994, p. 16).

While the constructivist model of environmental education appears to address many of the high-profile topics in today's educational discussions, concerns are still voiced over the effectiveness of such strategies in achieving the basic goals of the educational system. However, these concerns can be addressed by looking at the results generated by schools with environmental education programs. The 1998 report by the State Education and Environment Roundtable (SEER), Closing the Achievement Gap: Using the Environment as an Integrating Context for Learning, presented the results of a national study of 40 schools that used the environment as an integrating context (EIC) for learning. EIC-based learning is "about using a school's surroundings and community as a framework within which students can construct their own learning, guided by teachers and administrators using proven educational practices." (Lieberman & Hoody, 1998, p. iv) By analyzing the GPAs and the achievement on the standardized test by students at these schools, as well as interviewing the teachers and administrators, the authors

of the report found that students of programs using the environment as an integrating context outperformed students of other programs and schools, as well as their own past performance. According to the report, EIC students were found to more effectively master knowledge and skills, and achieve a deeper understanding of concepts and processes. They are also better able than other students to discern the connections between what they learn and possible connections to the real world. "Students in EIC programs are also better able than other students to discern the connections between what they learn...and possible applications in the real world" (Lieberman & Hoody, 1998, p. 45).

In addition to being an effective model for the teaching of academics, the SEER report concluded, based on the perceptions of teachers, that environmental education produced students that were more well-rounded socially as well. "Students are gaining basic life-skills -- better, more caring relationships, acting responsibly, working independently, cooperatively, and collaboratively, developing communication skills, seeking and demonstrating leadership, understanding thinking and communicating about issues larger than themselves, becoming involved in their communities. They develop confidence and a sense of ownership. The validity and significance of school increases. They have expanded opportunities for higher education and career options. And they are becoming life-long learners, capable of adapting to a rapidly changing world" (Sherman, 1998, p.

1). The teachers involved in programs that use the environment as an integrating context are also more enthusiastic about their role in the classroom.

While the use of environmental education as a vehicle for other subjects has shown to be effective, it can also be difficult for teachers, especially those new to environmental education, to implement. One of these problems is the finding of appropriate issues and topics to use as vehicles for other, more traditional subjects. Although there are several environmental education curricula that have been developed over the past couple of decades, the most used ones deal with very general issues and concepts. Few publications incorporate local science and history into the curriculum. However, using a school's local environment to teach students is very valuable. In his study on building a framework for environmental education, May (2000) found that most environmental educators agreed that a key element of this framework was the understanding of local to global connections. This is only possible through curricula that allow students the opportunity to test their knowledge in the real world. As curricula that address more specific regions tend to be rare, curriculum development at the local level is necessary because "many teachers do not know the surroundings of their schools and towns well enough" (Blum, 1987-1988, p. 5) to address local science and history on their own.

The positive aspects of technology with relation to the environment is often missing in curriculum as well. While

one of the basic issues to be addressed in environmental education is technology and the making of choices (Disinger & Roth, 1992, p. 2), this tends to take the form of the damages that our advancing technological society have contributed to the natural environment. While not perpetuating the idea that technology will "rescue us" from our poor choices, students must be made aware that technology can have a positive role with respect to the environment, not just the negative. Ramsey, Hungerford, and Volk (1992, p. 36) stated, "Environmental education must prepare individuals to be responsive to a rapidly changing technological world, to understand contemporary world problems and to provide the skills needed to play an affective role in the improvement and maintenance of the environment. Therefore, environmental education must incorporate many aspects of the environment: natural and manmade, technological, social, economic, political, cultural, and aesthetic." In other words, if environmental education is to be truly interdisciplinary in practice, then it must address all the issues upon which it touches.

Daniel S. Goldin, the Administrator for the National Aeronautics and Space Administration (NASA), spoke on the need to educate students in the uses of technology so that they will be able to respond to the growing environmental challenges of our society. In his report before the Committee on Science in 1999 explaining NASA's commitment to education, he stated that "Americans will soon be faced with

important decisions regarding clean air and water, noise pollution, sustainable development, the use of pesticides, and natural resource management. The remedies are often explained in technological terms and the consequences couched in scientific jargon. If we are to make rational decisions regarding these issues, and help guide the political process in a useful way, we need to have at least some understanding of complex technologies that are typically based in physics, chemistry, and biology" (p. 4) And what better way to "inspire America's students, create learning opportunities, and enlighten inquisitive minds" (Owens, 2000, p. 1) than through the air and space sciences which many students find so alluring?

However, NASA is not an education agency and it must rely on others to help communicate their knowledge to the educational establishment. One of the organizations assisting NASA is the Preservation of Aerospace Technologies, or PAT Projects, based out of the Society for Experimental Test Pilots chapter in Lancaster, California. The educational products produced by PAT Projects focus on the aerospace projects of nearby Dryden Flight Research Center, a NASA center at Edward's Air Force Base. In this way, students of the area are introduced to local science and history. The goal is to also produce curricula, through the teaming of K-12 teachers and some of the nation's most qualified test pilots and engineers, that excite students about learning and "emphasize (real-world) decision making

and give...an appreciation of the need to integrate many different skills, such as math, science, and communications, in the process" (Ottinger, 1998, p. 2). This project draws from the curricula developed by PAT Projects to create lessons that are constructivist in nature, and focus on the use of local aerospace science and history to convey basic concepts of environmental education to the students of the Antelope Valley area of California.

CHAPTER THREE

GOALS AND OBJECTIVES

The primary goal of this project was to develop a curriculum that addressed the local history and technology of the Antelope Valley, California, and combine it with basic concepts in environmental education for fourth grade classes. Oftentimes, when science is taught at the elementary level, students are not exposed to the real world applications of the concepts they are being taught in the classroom. This provides students not only with a frame of reference for remembering the concepts taught, but also with further motivation to learn the concepts. When students are interested in a subject, they are more excited and motivated to learn. Few things excite children as much as airplanes do. Providing real world connections also allows students the opportunity to explore new careers, or new applications of careers they were already aware of (such as a weather observer for a flight test facility).

Additionally, this curriculum was designed as an introduction for teachers and students to aerospace science. Aerospace science is deeply rooted in the history of the Antelope Valley. While many people often find it an interesting subject, most labor under the misconception that it is too "technical" to fully understand. Many educators are prey to this misconception as well believing that they are either ill equipped to teach such a "complex" discipline,

or that it is too complicated for their students to fully comprehend. However, aerospace science incorporates many subjects which educators already address in their classrooms, such as weather, mapping, electricity and circuits, geometry, and biology. The idea behind this project was to provide teachers with a resource that combined aerospace projects currently under design with the basic concepts of weather and mapping, all of which are a part of the fourth grade curriculum. This was done in the hopes of encouraging local educators to involve their students more deeply in their home area, while providing their students with an exciting and relevant learning experience.

CHAPTER FOUR

DESIGN OF PROJECT

The curriculum The X-33 and The X-38 Experimental Aircraft: Environmental Connections with Aerospace Science was designed to be used with fourth grade students. The project can be used in its entirety, or the individual lessons can be used separately. Instructors should utilize the lessons in a manner consistent with their own goals and time frame. Completing the entire curriculum requires four to six weeks.

This curriculum began as part of a joint effort between the National Aeronautics and Space Administration's (NASA) Dryden Flight Research Center (DFRC) at Edwards Air Force Base, California and the Preservation for Aerospace Technology (P.A.T.) Projects located in Lancaster, California. The education center at DFRC provided funding and personnel contacts for P.A.T. Projects to develop lessons based on current flight test projects for Kindergarten through twelfth grade.

The curriculum contained in this project began as lessons for the Kindergarten through fourth grade classroom, aligned to the national standards. In order to more closely align it with the goals of environmental education and the California educational standards, the scope was narrowed to include only fourth grade.

The background science and history for the lessons were

researched through numerous meetings with X-33 and X-38 engineers and pilots, as well as NASA education personnel. Several field trips to Lockheed Plant 42 and Edwards Air Force Base were also extremely useful. The lessons have been field tested, in their previous format, in beta tests in classrooms located near other NASA installations, as well as classrooms in the Antelope Valley. Over the course of the beta tests, the lessons were fine tuned to be more accessible to the average student.

CHAPTER FIVE

IMPLICATIONS FOR EDUCATORS

Most educators would agree that one of the most frequently asked questions in the classroom is, "Why do I need to know this?" For many students, the relevance of the concepts being taught is almost as important as the concepts themselves. When a student understands the importance and applicability of what they are being taught, it automatically gains importance over that which seems useless. It has been shown that students who know the real world applications of what they are being taught are more enthusiastic and attentive in the classroom. As a result, their retention, as well as their ability to apply their knowledge, noticeably increases.

In studying an environmental education curriculum that is based on aerospace technology, students are given real world applications of their knowledge that they find fascinating. This not only encourages their learning of the concepts, but opens up different pathways of thought for them as well. Instead of simply thinking about what a nice warm day it is, a student is instead encouraged to think about whether or not the weather might be good enough to launch the X-33. Instead of only using maps to find their way around town, students might instead think about how to use maps to land astronauts safely in the Crew Return Vehicle (of which the X-38 is the current prototype) in case of an emergency on

the International Space Station. New career opportunities also open up before students studying this curriculum.

Elementary educators most specifically need to find ways in which to stimulate their students to learn. In the upper grades, real world applications of science are easy to find as they are often based upon more complex concepts than those which elementary classrooms address. This curriculum motivates elementary students to learn the basic concepts of weather and geography by providing them with real world applications within their community.

This curriculum can be used, with little alteration, anywhere that the X-33 or the X-38 are flight tested. It will also remain useful in the future, with little alteration, as curriculum for the new space shuttle, of which the X-33 is the current prototype, and the Crew Return Vehicle for the International Space Station, of which the X-38 is the current prototype.

APPENDIX A:
STUDYING THE WEATHER
CONDITIONS NEEDED
TO LAUNCH THE
X-33

Objectives

- Students will analyze and predict weather conditions, using weather instruments and media sources.
- Students will compare their analysis of the weather with conditions necessary for the X-33 to launch.

Description

- Students will identify that the forces generated in the Earth's atmosphere, by the interaction of the energy of the sun with air, is weather.
- Students will chart and predict weather conditions using personal observation and media sources.
- Students will identify the weather conditions necessary for the X-33 to fly.
- Students will identify that weather conditions throughout the atmosphere affect human activities.

Science Standards

- Students will understand basic features of the earth.
- Students will understand energy types and sources, and conversions, and their relationship to heat and temperature.

Mathematics Standards

- Students will understand and apply basic and advanced properties of the concept of measurement.
- Students will effectively use a variety of strategies in the problem-solving process.

Processing Skills

- Observing
- Communicating
- Measuring
- Collecting Data
- Inferring
- Predicting
- Interpreting Data
- Making Graphs
- Hypothesizing
- Investigating

Management

This activity consists of an introduction and four additional parts. The introduction is designed to help develop your students' interest in the study of weather. Two activities are listed here, as well as a suggested reading list. You may use any or all of the parts as desired to catch the interest of your class.

All parts of this lesson may be done as whole class activities for a fourth grade class. It is recommended that

several days of follow up be allowed for each activity before the next is introduced. It is also recommended that lesson 4, "Is it safe for the X-33 to launch," be started at the beginning of this unit and carried through in conjunction with the other lesson in this unit. Allow 15-20 minutes for initial instruction for each activity, and 5-10 minutes daily for follow up. Optimally, each lesson should contain four to five days of follow up, or a new section should be introduced each week.

Background Information

Weather describes the condition of the air at a particular place and time. Weather changes constantly. Climate is the average weather conditions in one place. Before a launch of the X-33 can be initiated, certain weather conditions must exist to insure the safety of the vehicle and the environment in and around its flight path. The most important of these conditions are the current cloud cover and wind conditions. The X-33 requires wind speeds of no greater than 5 miles per hour (in later tests this limitation may be increased to 10 mph) for launch to occur. For the X-33 to make a successful landing the wind speeds must be no greater than 10 mph (in later tests this may be increased to 20 mph). This restriction is imposed in order to reduce the chances of the craft encountering any wind shear. In order for the X-33 to launch, the area in and around the flight path must be free of clouds. This limitation is imposed in order to eliminate the possibility of the craft encountering ice crystals.

Introduction

Part A: Creating a Rainstorm

Materials and Tools

- Reading selections as desired (suggested list provided after part 2)

Procedures

1. Divide your class into three or more groups.
2. Begin with all students snapping their fingers lightly, this will simulate a light rainfall.
3. Have each group switch from snapping their fingers lightly, to snapping them harder as you point to them in succession.
4. As you continue to point to each group have them change from snapping their fingers harder to slapping their thighs softly to slapping their thighs harder.
5. When all students are slapping their thighs you'll have a full-fledged rainstorm!

Part B: A Walk in a Virtual Rainstorm

Materials and Tools

- Reading selections as desired (a suggested list is provided in the Extensions section at the end of this lesson)

Procedures

1. Inform your students that they will be trying to picture in their minds as clearly and vividly as possible the conditions that you will be verbally providing them with. (You may wish to play some music during the activity, a suggestion is the Grand Canyon Suite).
2. Have the students find a comfortable place, away from distraction. Have them then close their eyes.
3. Describe to your students the experience of being in a storm. A suggested script is provided in the Extensions section at the end of this lesson.
4. You may choose to follow this experience with a journal writing, or an art project illustrating the storm the students experienced.

Part 1: Observing the Weather

Materials and Tools

- Poster board or butcher paper
- Markers (permanent and wet-erase)
- Thermometer(s)
- "Reading a Thermometer" handout #1 (p. 36)
- Weather calendar (may simply be piece of tagboard, grided for a calendar, and laminated)
- Books, magazines, pictures, and/or other items on the subject of weather

Procedures

1. Set up a Weather Center in your room. This should consist of a weather calendar, and a large piece of paper titled "Weather Words." You may also wish to include books, magazines, and pictures about the weather.
2. Place a thermometer outside, well away from natural and built structures. These may affect the temperature reading as all structures give off heat. For older grades you may wish to place a thermometer in the shade as well, so that you may compare the temperature differences between the two areas.
3. Ask the students what a meteorologist does. Discuss with students that a meteorologist is a scientist who studies and predicts the weather, and that a meteorologist is a very important member of the X-33 team. Tell the students that they are going to learn to be meteorologists.
4. As a class, brainstorm individual words that have to do with the weather, put these on the "Weather Words" sheet.
5. As a group (or individually for more advanced students) develop a definition for weather. (Example: Weather is what is happening with the air outside). Put your definition for weather near your weather calendar.
6. Explain that the temperature of the air is a part of weather.
7. Discuss that temperature is a measurement of how much the sun is heating the air. Ask the students how the temperature outside can change. Discuss the change in the temperature of the air as the sun rises and sets each day.
8. Discuss that meteorologists measure temperature with a thermometer. A thermometer is a tube with liquid inside. As the temperature rises, so does the liquid in the tube. Depending on the ability level of your class, you can use handout #1, "Reading a Thermometer," as an

overhead activity, or individually. With lower grades it may be good to have examples of different temperatures available.

9. As a whole class, or in partner groups, chart the weather on your calendar daily. This should include whether the weather is sunny, cloudy, rainy, etc. On a piece of butcher paper, graph the daily changes in temperature. If your students will be reporting the weather in partner groups, write their names in wet-erase marker on the calendar for them to keep track of. See if your students can predict the next day's weather based on the patterns from the previous day's reports.
10. Optional: Before each days presentation, as a whole class, say or sing a tune or poem about the weather, a pre-existing one, or one created by the class. An example of one tune, "Whether the Weather," can be found in the extensions located after this lesson. (This song can also work well to introduce homophones and homonyms)
11. As the class becomes more adept at charting the weather, have the students gather weather reports from various media sources. These may include the newspaper, radio, television, and the internet. Discuss why the reports may differ from the reports of your class.

Part 2: The Clouds Above Us

Materials and Tools

- "The Layers of the Earth's Atmosphere" handout #2 (p 38)
- "The Different Types of Clouds" handout #3 (p 40-47)
- Weather Center (developed in Part 1)

Procedures

1. Ask the students how thick they think the air around the Earth is. Discuss with students that all the air around the Earth is called the atmosphere. There are five major layers of the atmosphere: the exosphere, the thermosphere, the mesosphere, the stratosphere, and the troposphere. The troposphere is where all the weather occurs. Individually, or as a whole group (as a overhead), fill out "The Layers of the Earth's Atmosphere" handout, and have students color it.
2. Discuss with students that there is a very small amount of water vapor in the air (about 1 to 4 percent) and that sometimes we can see it as clouds. You may wish to use the example of steam to explain water vapor. Clouds form when the air becomes cool enough for the water vapor to come together. This is called condensation.
3. Discuss that clouds can look different if they form at different heights in the troposphere. Use the information sheet "The Different Types of Clouds" as a handout or overhead to discuss the different types of clouds.
4. Take the students outside to observe the sky (pick a day when there are clouds in the sky). Have each student sketch 2-4 different types of clouds they see in the sky. Students should then illustrate the clouds they saw (by drawing or creating, perhaps with cotton balls), and name the clouds.

Assessment

1. Daily, as partner groups or a whole class, add the types of clouds found in the sky to your weather report.

Part 3:

Wind

Materials and Tools

- 6" squares of construction paper (one for each student)
- Paper beads (see step 3a for construction)
- Pencils with erasers (one for each student)
- Paper
- Glue
- Straight pins
- "Beaufort Wind Scale" handout #4 (p 48-49)
- "Wild Wind Word Find" handout #5 (p 50)

Procedures

1. Ask students what they think wind is, and how it is generated. Chart their answers. Discuss with students that wind occurs due to the uneven heating of the air by the sun. As a mass of warm air meets a mass of cool air, wind is created.
2. Ask students how many words they can think of that are synonyms for "wind." Discuss that every different language has its own word for "wind." Have the students complete the Wild Wind Word Find.
3. Ask students how they think they could measure how strong the wind is blowing. Discuss with students that you can measure the force/speed of the wind with an instrument called an anemometer. Discuss the Beaufort scale with students. An example of the scale is located in the extensions section at the end of this lesson.
4. Construct "anemometer" (for a closer approximation to a real anemometer, please see the extension below).
 - a. Make paper beads, one for each student, by rolling up thin strips of paper and gluing the ends down.
 - b. Give each student a 6" square of construction paper (if you choose, have them decorate the paper on both sides).
 - c. Have students fold their paper diagonally, both ways. The creases should form an "x."
 - d. Have students cut down each crease to about 1" from the center of the square (there will be four cuts).
 - e. Have students bring every other corner into the center, make sure that the corners overlap.
 - f. Push a pin through the center of the paper, making sure that it goes through each of the four folded down corners.
 - g. Put a paper bead on the pin, and push the pin into the side of the eraser on a pencil.
5. Count the number of turns the anemometer makes in 10 seconds, this is the Beaufort number. Use the anemometer and the Beaufort Wind Scale handout to

measure the wind daily. Add this to your daily weather reports.

Extension: To make a more advanced anemometer:

Materials (per anemometer):

- 4 Spray can caps
- 2 thin wood strips approx. 6 inches long, with a hole drilled through the middle to match the size of the dowel.
- 1 1/2-gallon milk carton
- wooden dowel
- 2 washers (to fit dowel)
- thumb tacks
- plaster

Directions:

1. Glue 1 spray can cap to each end of the 2 wood strips.
2. Glue the strips together at 90 degree angles, matching the holes in the middle.
3. Slip a washer onto a wood dowel.
4. Place the wood dowel through the holes in the wood strips.
5. Place another washer on the dowel and secure the dowel with a thumb tack.
6. Cut a milk carton in half.
7. Mix plaster with water and pour into the bottom half of the milk carton.
8. Push the free end of the dowel into the center of the plaster and hold steady until the plaster hardens.
9. To use your anemometer, place it on a level surface in the wind. Count the number of complete turns that the colored cups make in 10 seconds, and compare to the Beaufort Wind Chart.

Part 4:
Is It Safe for the X-33 to Launch?

Materials and Tools

- Weather Center
- Butcher paper
- markers

Procedures

1. Discuss with students the weather conditions that need to exist in order for the X-33 to launch (see Background Information). Chart them on butcher paper. Discuss why these are important. Post these conditions in the Weather Center.
2. Add to your daily weather report, whether or not the conditions are right to launch the X-33.

Extensions for Lesson 1:

Suggested Script for Introduction: Part B

It is a cool summer's evening. You hear the sounds of crickets and small frogs, the sounds of summer. A cool breeze picks up, and brushes against your cheek. The air around you smells different, metallic, you can almost taste it. In the distance, clouds have covered the moon, but it isn't dark. The sky is broken by bright flashes of lightening. After a long wait, you hear a low rumble that tells you the storm is far away. You watch and listen as the storm gets closer. Suddenly a bright flash of lightening tears the sky over your head. The roar of thunder breaks at almost the same instant. Looking up, you feel the first soft drops of rain from the clouds overhead. It begins to rain harder and harder. You can hear it hitting the earth around, making a rich, deep sound. You feel it against your skin as it soaks your hair and clothes. Then the rain begins to fall softer and softer, and there is no longer any lightening or thunder. The rain stops, and you breathe in the freshly cleaned air deep into your lungs. The storm has passed and all is quiet. Slowly the sound of the animals returns. (Note: wait a moment before telling your students to open their eyes).

Suggested Reading List for Introduction: Part B

Bringing the Rain to Kapiti Plain, Verna Aardema, Dial Books, 1981
The Cloud Book, Tomie De Paulo, Holiday House, 1975
Gilberto and the Wind, Mary Hall Ets
Weather Forecasting, Gail Gibbons
Weather Words, Gail Gibbons
Junior Science Weather, Terry Jennings
National Audubon Society First Field Guide: Weather, Jonathan D. W. Kahl, Scholastic, 1998
The Snowy Day, Ezra Jack Keats
Mirandy and Brother Wind, Patricia McKissack
What Makes the Wind?, Laurence Santrey, Troll Associates, 1982
Rain Rain Rivers, Uri Shulevitz
Weather Experiments, Vera Webster
Umbrella, Taro Yashima, Viking, 1958

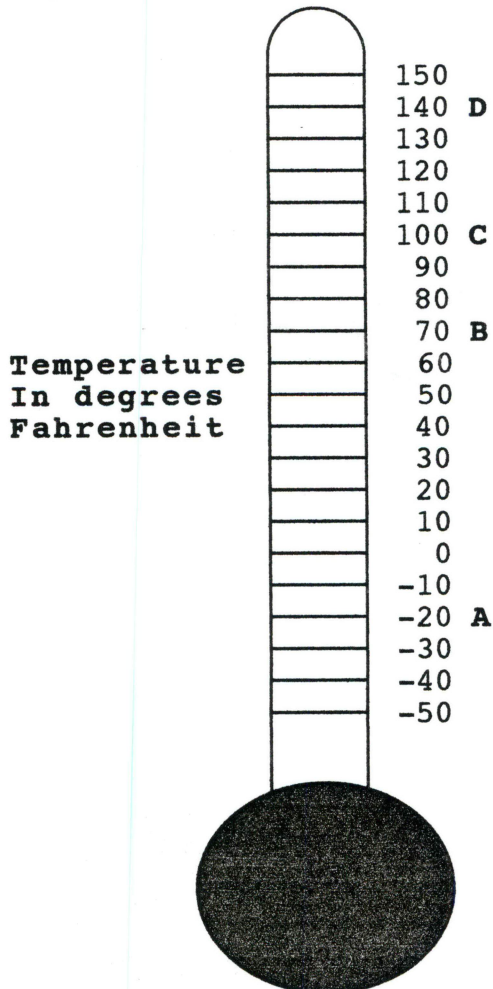
Wild Weather Song

Whether the Weather
Whether the weather be fine,
Or whether the weather be not.
Whether the weather be cold,
Or whether the weather be hot.
We'll weather the weather,
Whatever the weather,
Whether we like it or not! (clap, clap)
Whether we like it or not! (clap, clap)

Reading a Fahrenheit Thermometer Handout #1

Temperature is how hot or how cold something is. Temperature is a very important part of weather because the differences in temperature are what cause winds to blow and rain to fall from clouds. Knowing the temperature of the air, and how it changes over many days, can help you to be able to predict the weather. A thermometer is an instrument used to record the temperature of the air and other things. There are two scales most commonly used on thermometers. These scales, named after the scientists who developed them, are the Fahrenheit and Celsius scales. In the United States we use the Fahrenheit Scale for recording temperature.

A normal body temperature for a human is 98 degrees Fahrenheit. If you also know that water freezes at 32 degrees Fahrenheit and 0 degrees Celsius, and water boils at 212 degrees Fahrenheit and 100 degrees Celsius, can you figure out the problems below?



Fill in the blanks with a letter from the thermometer that represents the correct temperature.

1. A comfortable room temperature. _____

2. A bowl of hot soup. _____

3. A scoop of ice cream. _____

4. A warm summer's day. _____

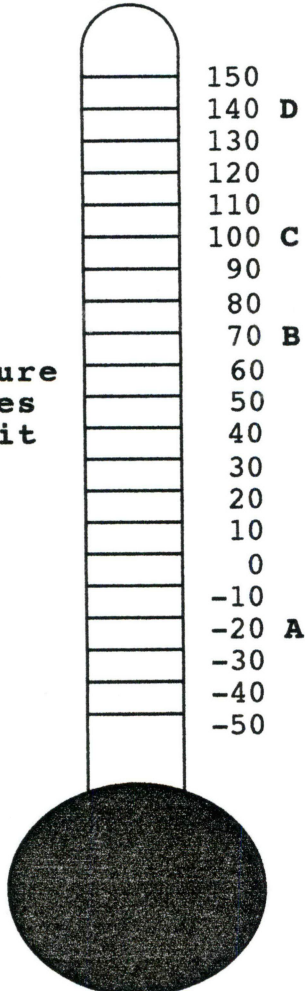
Reading a Fahrenheit Thermometer

Handout #1--KEY

Temperature is how hot or how cold something is. Temperature is a very important part of weather because the differences in temperature are what cause winds to blow and rain to fall from clouds. Knowing the temperature of the air, and how it changes over many days, can help you to be able to predict the weather. A thermometer is an instrument used to record the temperature of the air and other things. There are two scales most commonly used on thermometers. These scales, named after the scientists who developed them, are the Fahrenheit and Celsius scales. In the United States we use the Fahrenheit Scale for recording temperature.

A normal body temperature for a human is 98 degrees Fahrenheit. If you also know that water freezes at 32 degrees Fahrenheit and 0 degrees Celsius, and water boils at 212 degrees Fahrenheit and 100 degrees Celsius, can you figure out the problems below?

**Temperature
In degrees
Fahrenheit**

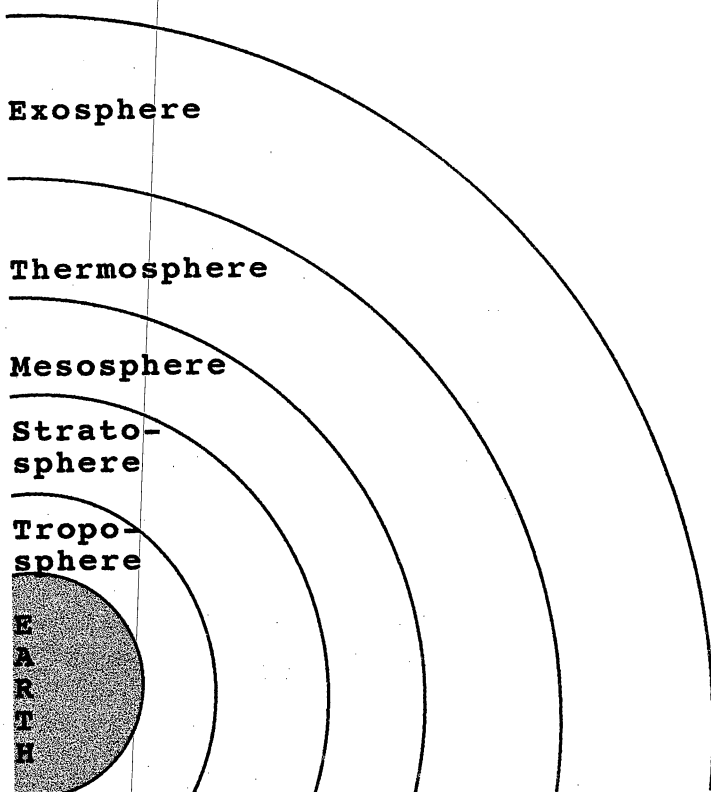


Fill in the blanks with a letter from the thermometer that represents the correct temperature.

1. A comfortable room temperature. B
2. A bowl of hot soup. D
3. A scoop of ice cream. A
4. A warm summer's day. C

Layers of the Earth's Atmosphere Handout #2

Fill in the blanks in the questions below with the words from the word bank.



Word Bank	Color
Exosphere	<div style="width: 20px; height: 10px; background-color: white; border: 1px solid black;"></div>
Mesosphere	<div style="width: 20px; height: 10px; background-color: #f0f0f0; border: 1px solid black;"></div>
Stratosphere	<div style="width: 20px; height: 10px; background-color: #e0e0e0; border: 1px solid black;"></div>
Thermosphere	<div style="width: 20px; height: 10px; background-color: #d0d0d0; border: 1px solid black;"></div>
Troposphere	<div style="width: 20px; height: 10px; background-color: #c0c0c0; border: 1px solid black;"></div>

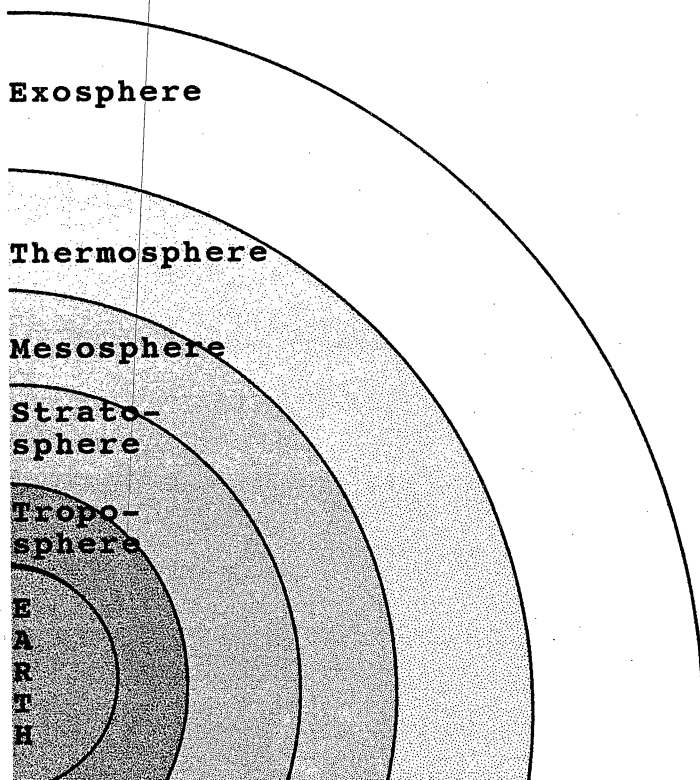
Questions:

1. Layer A is the layer of the atmosphere where all the weather occurs. It occurs from 0-10 miles (0-16.1km) from the Earth's surface.
This layer is the _____.
2. Layer B is the layer of the atmosphere where the ozone layer is. It occurs from 10-30 miles (16.1-50km) from the Earth's surface.
This layer is the _____.
3. Layer C is the layer of the atmosphere where the temperature starts to drop sharply. It occurs from 30-50 miles (50-80km) from the Earth's surface.
This layer is the _____.
4. Layer D is the layer of the atmosphere where the aurora borealis occurs. It occurs from 50-400 miles (80-640km) from the Earth's surface.
This layer is the _____.
5. Layer E is the layer of the atmosphere closest to the vacuum of outer space. It occurs from 400-40,000 miles (640-64,400km) from the Earth's surface.
This layer is the _____.

Layers of the Earth's Atmosphere

Handout #2--KEY

Fill in the blanks in the questions below with the words from the word bank.



Word Bank	Color
Exosphere	
Mesosphere	
Stratosphere	
Thermosphere	
Troposphere	

Questions:

1. Layer A is the layer of the atmosphere where all the weather occurs. It occurs from 0-10 miles (0-16.1km) from the Earth's surface.

This layer is the Troposphere.

2. Layer B is the layer of the atmosphere where the ozone layer is. It occurs from 10-30 miles (16.1-50km) from the Earth's surface.

This layer is the Stratosphere.

3. Layer C is the layer of the atmosphere where the temperature starts to drop sharply. It occurs from 30-50 miles (50-80km) from the Earth's surface.

This layer is the Mesosphere.

4. Layer D is the layer of the atmosphere where the aurora borealis occurs. It occurs from 50-400 miles (80-640km) from the Earth's surface.

This layer is the Thermosphere.

5. Layer E is the layer of the atmosphere closest to the vacuum of outer space. It occurs from 400-40,000 miles (640-64,400km) from the Earth's surface.

This layer is the Exosphere.

The Different Types of Clouds

Handout #3

Clouds are classified into a system that uses Latin words to describe the appearance of clouds as seen by an observer on the ground. The table below lists the four basic categories used to classify clouds.

<u>Latin Root</u>	<u>Translation</u>	<u>Example</u>
cumulus	heap	fair weather cumulus
strat	layer	altostratus
cirrus	curl of hair	cirrus
nimbus	rain	cumulonimbus

Further classification identifies clouds by height of cloud base. There are four major classifications of clouds: low level, middle level, high level, and vertically developed. The names of the clouds often identify at which level they would be found. For example, cloud names containing the prefix "cirr-" are located at high levels, (such as cirrus clouds), while cloud names with the prefix "alto-" are found at middle levels, (as in altostratus clouds).

The following pages give examples of the most common cloud types found in each of these categories

High-Level Clouds

High-level clouds form above 20,000 feet (6,000 meters) and since the temperatures are so cold at such high elevations, these clouds are primarily made of ice crystals. High-level clouds usually look thin and white, but can appear in many colors when the sun is low on the horizon. Cloud types include cirrus and cirrostratus.

Cirrus Clouds thin and wispy

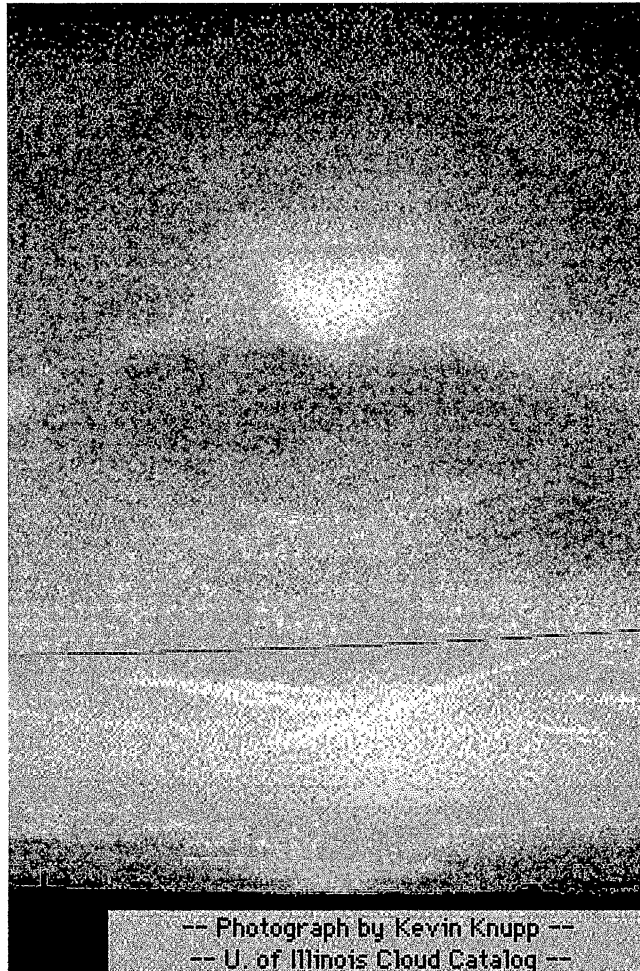
The most common form of high-level clouds are thin and often wispy cirrus clouds. Usually found at heights greater than 20,000 feet (6,000 meters), cirrus clouds are made of ice crystals. Cirrus generally occur in fair weather and point in the direction of air movement at their elevation.



-- U. of Illinois Cloud Catalog --

Cirrostratus Clouds
sheet-like and nearly transparent

Cirrostratus are sheet-like, high-level clouds made of ice crystals. Though cirrostratus can cover the entire sky and be up to several thousand feet thick, they are relatively transparent, as the sun or the moon can easily be seen through them. Sometimes you only know they're there by a halo around the sun or moon.

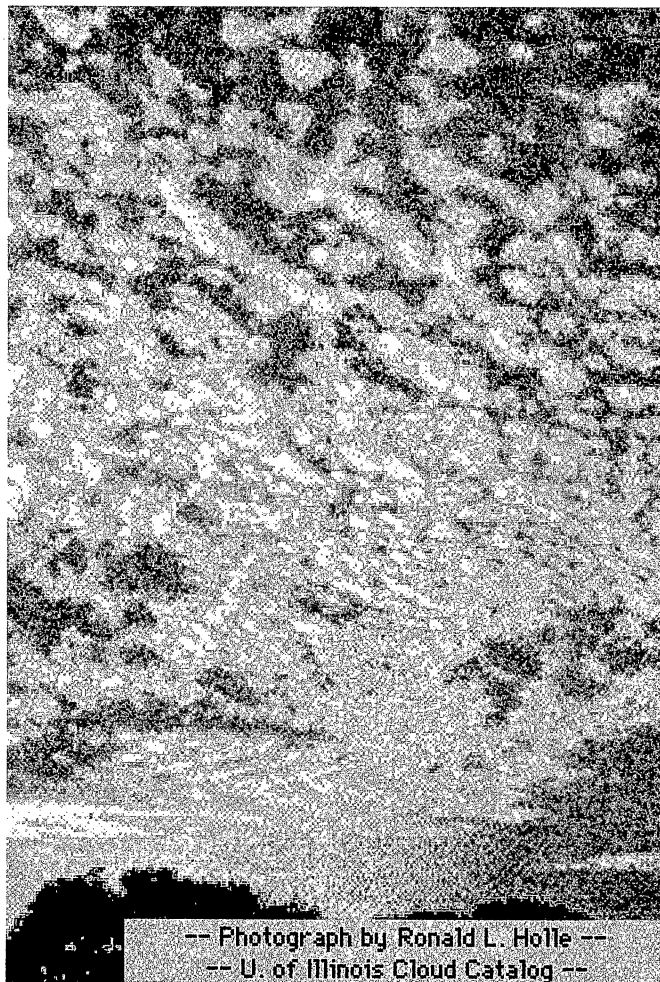


Mid-Level Clouds

The bases of mid-level clouds usually appear between 6,500 to 20,000 feet (2,000 to 6,000 meters). Because of their lower altitudes, they are mostly made of water droplets, however, they can also be made of ice crystals when temperatures are cold enough. Cloud types include altocumulus, altostratus.

Altocumulus Clouds parallel bands or rounded masses

Altocumulus may appear as parallel bands or rounded masses. Usually part of an altocumulus cloud is shaded, which makes them distinguishable from the high-level cirrocumulus. The presence of altocumulus clouds on a warm and humid summer morning is commonly followed by thunderstorms later in the day.



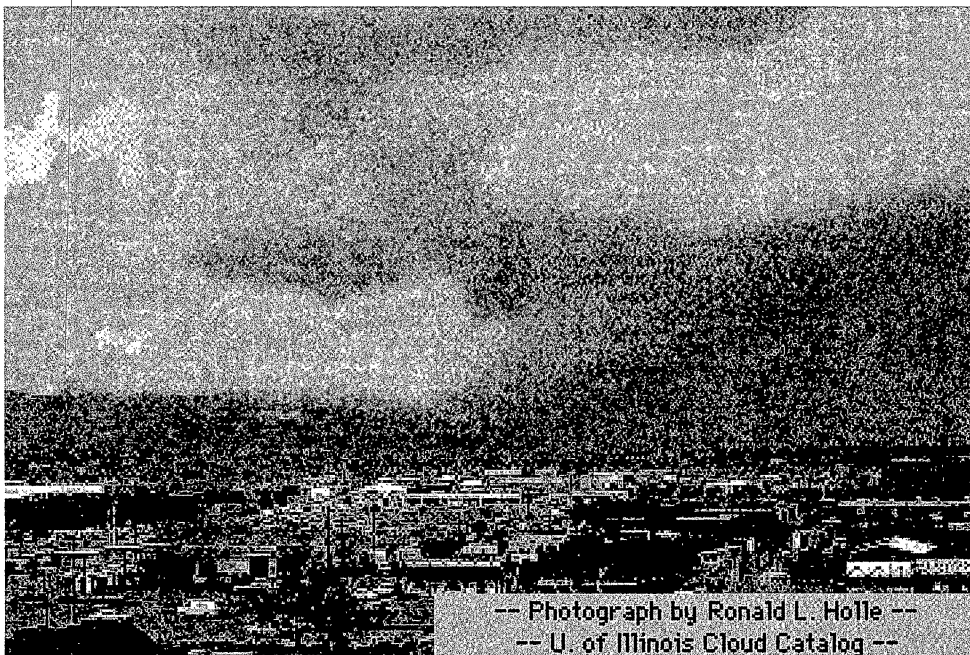
Low-Level Clouds

Low clouds are mostly made of water droplets since their bases generally lie below 6,500 feet (2,000 meters). However, when temperatures are cold enough, these clouds may also contain ice particles and snow. Cloud types include nimbostratus and stratocumulus.

Nimbostratus Clouds

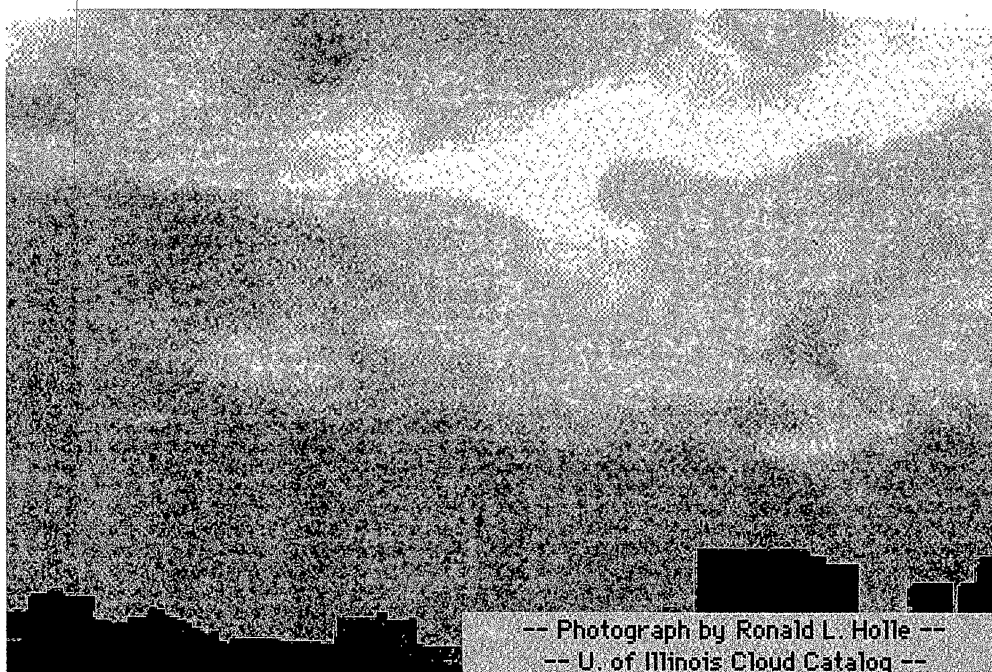
dark, low-level clouds with precipitation

Nimbostratus are dark, low-level clouds accompanied by light to moderately falling precipitation.



Stratocumulus Clouds
low, lumpy layer of clouds

Stratocumulus clouds usually appear as a low, lumpy layer of clouds that is sometimes accompanied by light precipitation. Stratocumulus can be dark gray to light gray and may appear as rounded masses, rolls, etc., with breaks of clear sky in between.



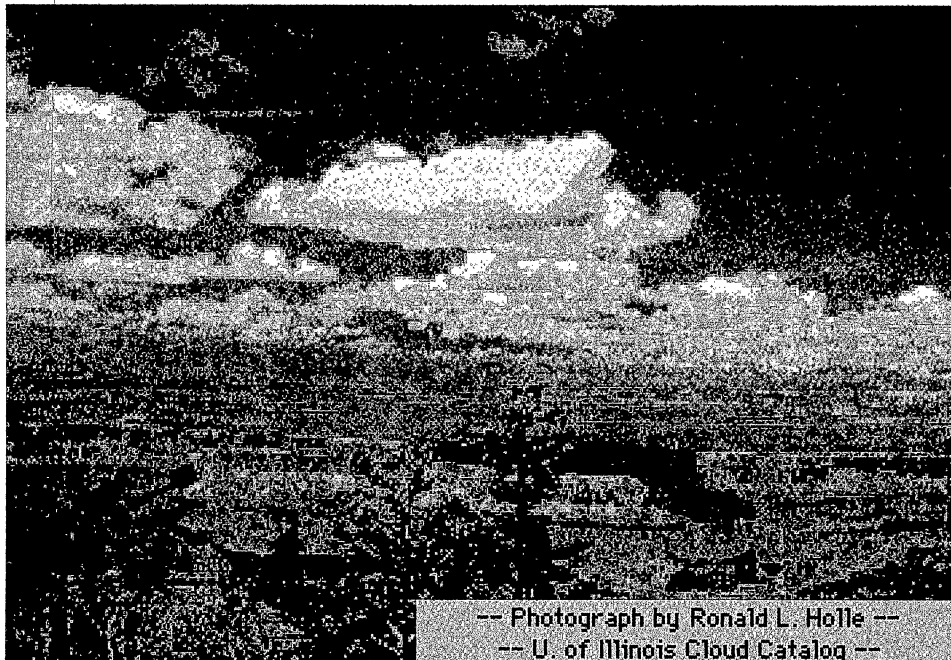
Vertically Developed Clouds

Probably the most familiar cloud is the cumulus cloud. These clouds can grow to heights in excess of 39,000 feet (12,000 meters). Cloud types include fair weather cumulus and cumulonimbus.

Fair Weather Cumulus Clouds

puffy cotton balls floating in the sky

Fair weather cumulus look like floating cotton and have a lifetime of 5-40 minutes. Known for their flat bases and distinct outlines, fair weather cumulus exhibit only slight vertical growth, with the cloud tops showing the limit of the rising air. Given good conditions, however, harmless fair weather cumulus can later develop into towering cumulonimbus clouds associated with powerful thunderstorms.

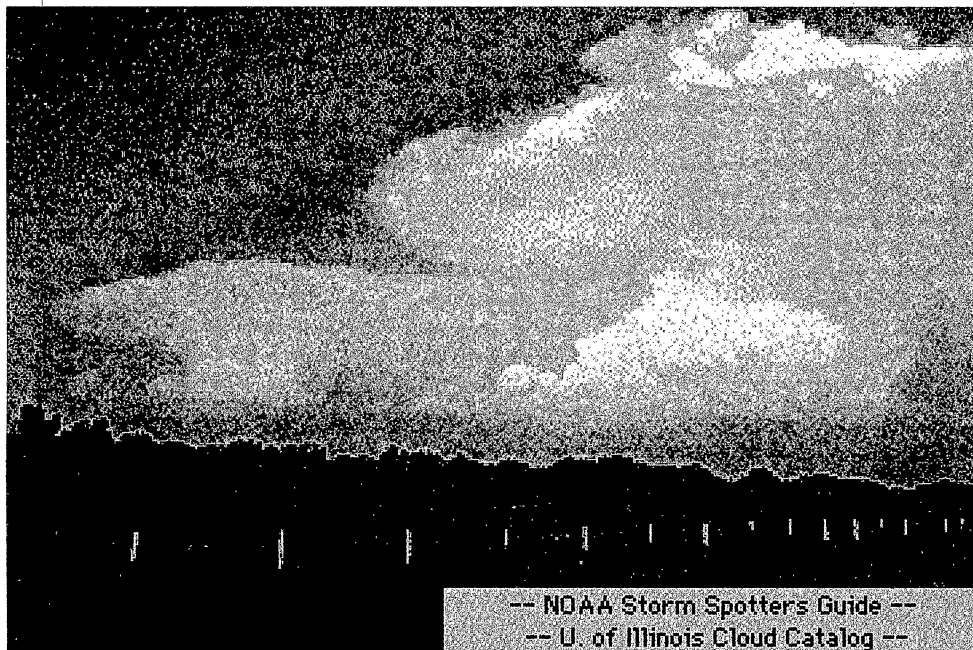


-- Photograph by Ronald L. Holle --
-- U. of Illinois Cloud Catalog --

Cumulonimbus Clouds

reaching high into the atmosphere

Cumulonimbus clouds are much larger and taller than fair weather cumulus. They can exist as individual towers or form a line of towers called a squall line. The tops of cumulonimbus clouds can easily reach 39,000 feet (12,000 meters) or higher.



Other Cloud Types

There is also a collection of miscellaneous cloud types which do not fit into the previous four groups. These cloud types include contrails, billow clouds, mammatus, orographic and pileus clouds.

Source: Hall, S., et al. (1999, October 25). WW2010: The weather world 2010 project. Retrieved January 8, 2001 from the World Wide Web:
[http://ww2010.atmos.uiuc.edu/\(Gh\)/home.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/home.rxml)

**Beaufort Wind Scale
Handout #4**

<u>Beaufort Number</u>	<u>Description</u>	<u>Wind Speed</u>			<u>Observations</u>
		<u>MPH</u>	<u>KPH</u>	<u>Knots</u>	
0	Calm	0	0	0	Tree leaves don't move; smoke rises vertically; sea is calm;
1	Light Air	1-3	1-5	1-3	Tree Leaves don't move; smoke drifts slowly; sea is lightly rippled;
2	Slight Breeze	4-7	6-11	4-6	Tree Leaves Rustle; flags wave slightly; small wavelets or scale waves
3	Gentle Breeze	8-12	12-19	7-10	Leaves and twigs in constant motion; small flags extended; long unbreaking waves
4	Moderate Breeze	13-18	20-29	11-16	Small branches move; flags flap; waves with some whitecaps
5	Fresh Breeze	19-24	30-38	17-21	Small trees sway; flags flap and ripple; moderate waves with many whitecaps

<u>Beaufort</u> <u>Number</u>	<u>Description</u>	<u>Wind Speed</u>			<u>Observations</u>
		<u>MPH</u>	<u>KPH</u>	<u>Knots</u>	
6	Strong Breeze	25-31	39-50	22-27	Large branches sway; flags beat and pop; larger waves with regular whitecaps
7	Moderate Gale	32-38	51-61	28-33	Whole trees sway; large waves ("heaping sea")
8	Fresh Gale	39-46	62-74	34-40	Twigs break off trees; moderately high sea with blowing foam
9	Strong Gale	47-54	75-86	41-47	Branches break off trees; shingles blown from roofs; high crested waves
10	Whole Gale	55-63	87-101	48-55	Some trees blown down; damage to buildings; high churning white sea
11	Storm	64-74	102-120	56-63	Widespread damage to trees and buildings; mountainous waves
12	Hurricane	75+	120+	64+	Severe and extensive damage

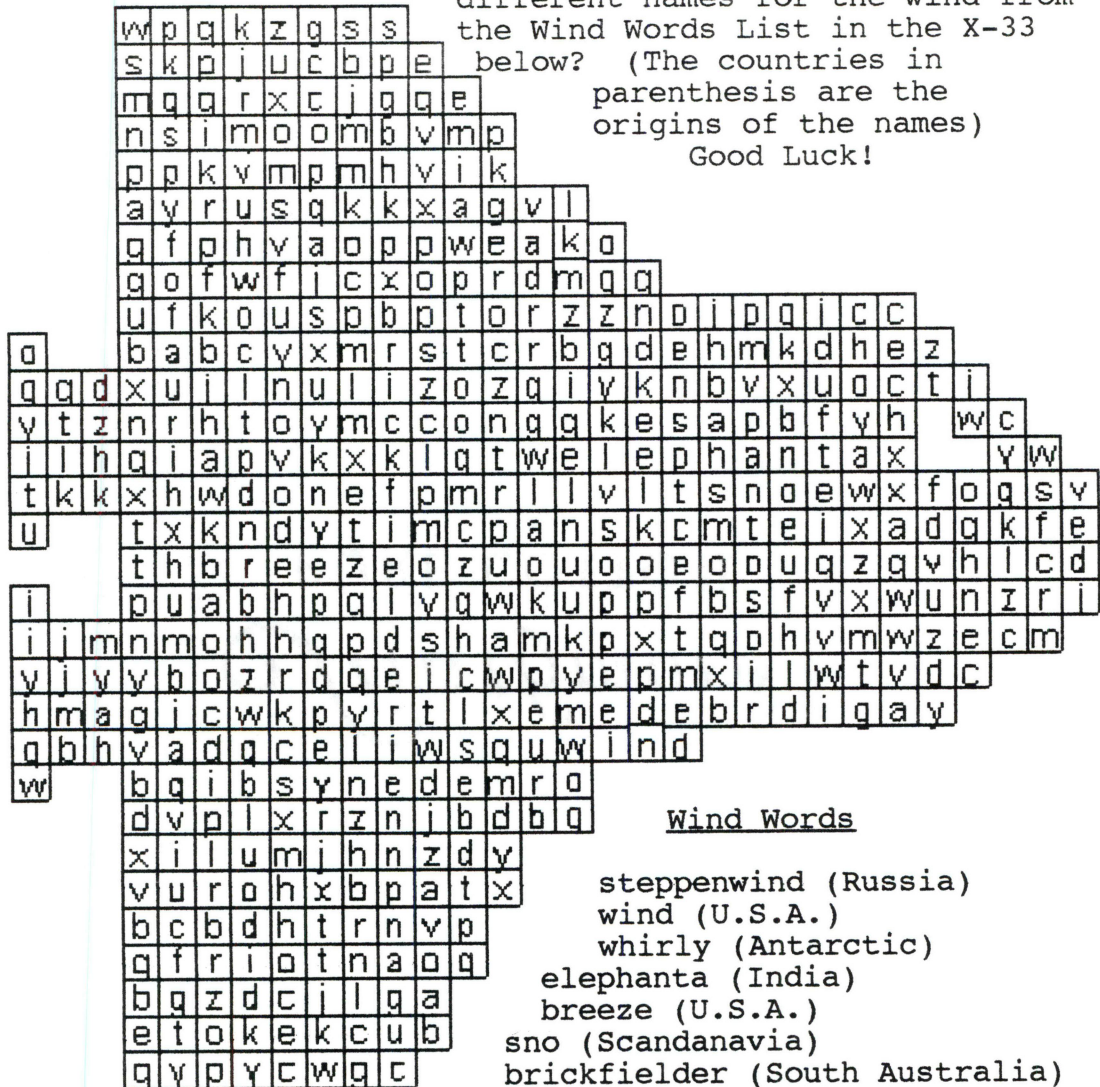
Wild Wind Word Find
Handout #5

Wind occurs in every place that the X-33 might land all over the world. In each country, wind has a different name in every language. Can you find the

different names for the wind from
the Wind Words List in the X-33
below? (The countries in

parenthesis are the
origins of the names)

Good Luck!



Wind Words

steppenwind (Russia)

wind (U.S.A.)

whirly (Antarctic)

elephantā (India)

breeze (U.S.A.)

sno (Scandinavia)

brickfielder (South Australia)

cockeye bob (Northwest Australia)

simoom (North Central Africa)

bull's eye squall (South Africa)

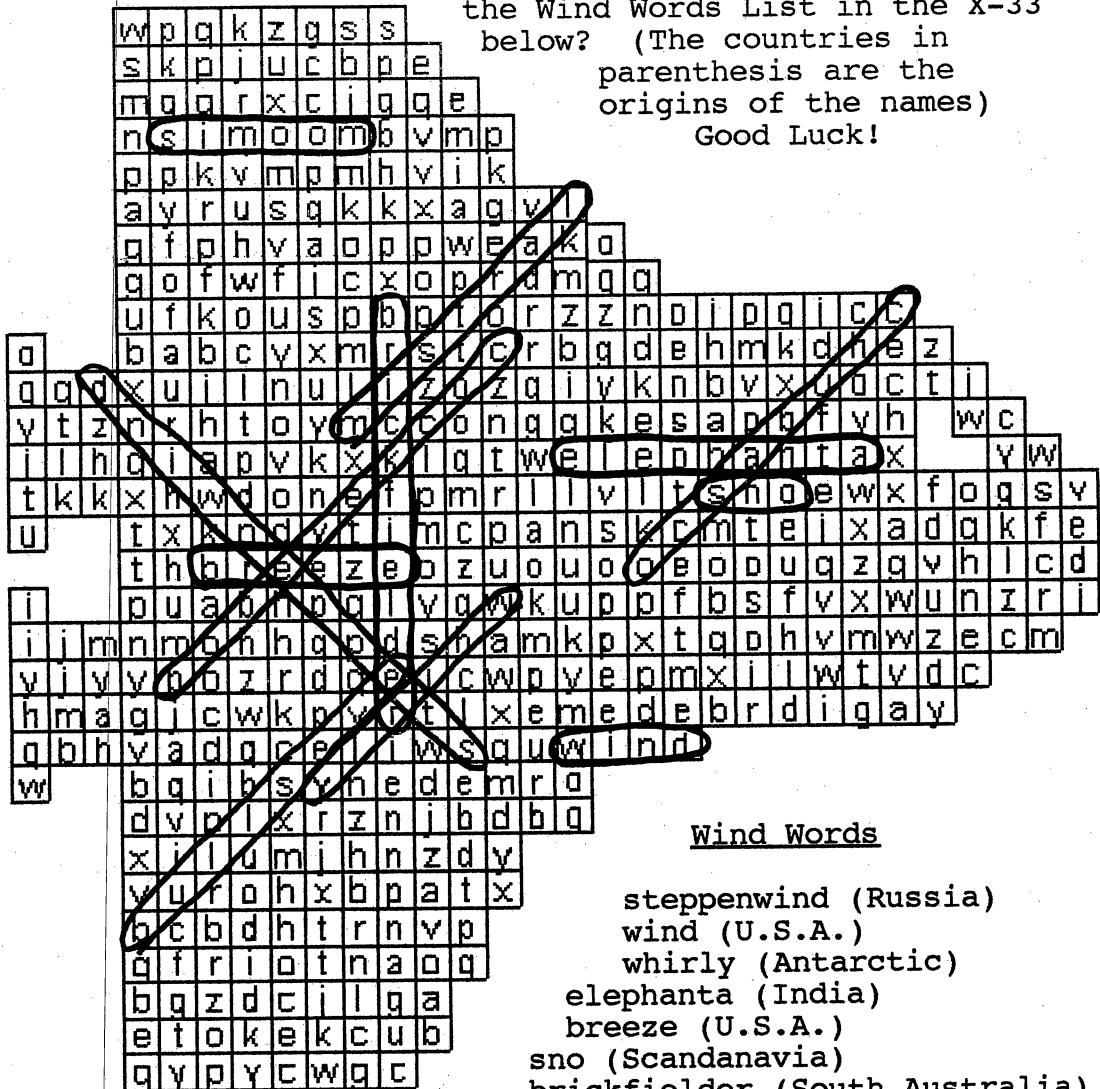
chubasco (Mexico and Central America)

mistral (Northwest Mediterranean)

Wild Wind Word Find Handout #5--KEY

Wind occurs in every place that the X-33 might land all over the world. In each country, wind has a different name in every language. Can you find the different names for the wind from the Wind Words List in the X-33 below? (The countries in

parenthesis are the origins of the names)
Good Luck!



Wind Words

- steppenwind (Russia)
- wind (U.S.A.)
- whirly (Antarctic)
- elephanta (India)
- breeze (U.S.A.)
- sno (Scandanavia)
- brickfielder (South Australia)
- cockeye bob (Northwest Australia)
- simoom (North Central Africa)
- bulls eye squall (South Africa)
- chubasco (Mexico and Central America)
- mistral (Northwest Mediterranean)

APPENDIX B:
GEOGRAPHY AND THE
X-38/CREW RETURN
VEHICLE (CRV)

Objectives:

- Students will identify how the rotation of the Earth in relation to the Sun produces the diurnal (day-night) cycle.
- Students will identify that different time zones are produced by the rotation of the Earth.
- Students will identify the uses of lines of longitude and latitude in determining global position.

Description:

- Students will determine that the factors of determining a landing site for the X-38 include the time zone the proposed site is in, as well as the latitude and longitude of the proposed site.

Science Standards:

- Students will understand basic features of the Earth.
- Students will understand essential ideas about the composition and structure of the universe and the Earth's place in it.
- Students will understand motion and the principles that explain it.

Mathematics Standards:

- Students will understand and apply basic and advanced properties of the concept of numbers.
- Students will understand and apply basic and advanced concepts of data analysis and distributions.

Processing Skills:

- Communicating
- Predicting

Management:

This activity is in three parts. Each part can be done as a whole class lesson for fourth grade. Allow a class period of 20-30 minutes for part 1. Allow two to three class sessions of 20-30 minutes each for parts 2 and 3.

For part 2, you can either use Handout #1, "Earth's Time Zones," as a handout for the entire class, or you may enlarge it to poster size if you have the resources available. In the Extensions section is an enlarged copy of the handout separated onto 12 pages, #7a-1, with the time zones removed, to be used instead of Handout #1. This activity can be done either as a whole class, or in small groups.

Each worksheet in part 3 can be done individually, in small groups, or as a whole class, depending on the skill level of the class. If the worksheets are done as a whole class, consider making a copy to be used as an overhead transparency.

Background Information:

The Diurnal Cycle

When the Earth rotates about its axis, different parts of it are exposed to the Sun's rays (the Earth rotates about its own axis about once every 24 hours, or a solar day). As the Earth rotates, new parts of the planet are continuously coming into contact with the Sun's rays, while other parts are continuously rotating into shadow. This causes the day and night, or diurnal, cycle. In this way morning dawns, the Sun is straight overhead (noon), and the Sun sets on different parts of the Earth at different times. For example; when it is dawn in California, it is usually around sunset in London. Time zones were established in order to make the relationship between the time of day, according to a clock, and the position of the sun constant for everyone.

Time Zones

The Earth is divided into 24 different time zones, one for each hour of the day. Each area of the Earth where morning dawns at roughly the same time is said to be in the same time zone, these generally fall in the boundaries between two meridians. A meridian is defined as a half circle passing through two places that see the sun at the same angle, and terminating at the North and South poles, the Prime Meridian and the International Date Line are two examples of meridians. Some time zone boundaries don't follow the meridians, but instead zigzag so that people living in one region or country can live in the same time zone, and some countries do not pay attention to the time zones at all. For example, China passes through five time zones, but operates under only one. Refer to Handout #1 for a graphic example of Earth's time zones.

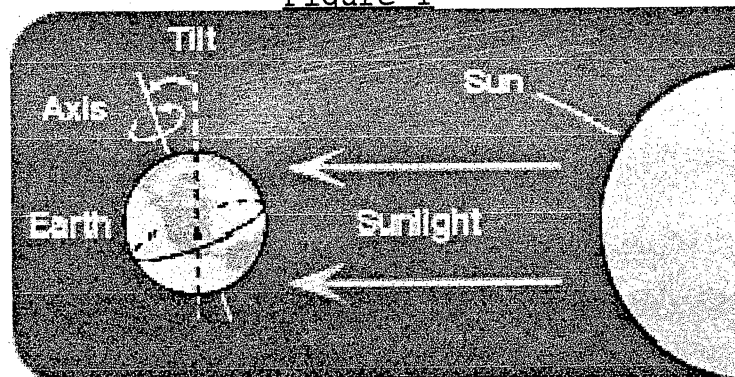
The time in Greenwich, England is considered to be Universal Time (UT), but is often referred to as Greenwich Mean Time (GMT). Many institutions, such as the military and many European countries, use a 24 hour clock instead of a 12 hour clock. A 24 hour clock helps to reduce the confusion that can be produced by duplicate numbers in the same day. For example, instead of 12:00 a.m. and 12:00 p.m., a 24 hour clock would read 00:00 and 12:00. The meridian that runs through Greenwich is the Prime Meridian. At 180° degrees around the earth, the International Date Line is its opposite. When it is 12:00 am (00:00) GMT it is 12:00 pm (12:00) at the International Date Line. The International Date Line is where each new "day" begins according to a clock. When you cross the International Date Line, the date changes as well as the time. Refer to student Handout #1, "Earth's Time Zones," for a graphic example.

The Seasons

The Seasons

Earth is, for all intents and purposes, round (a sphere). If you look at a globe, you'll notice that the Earth is tilted about its axis (or "tipped over") (Figure 1).

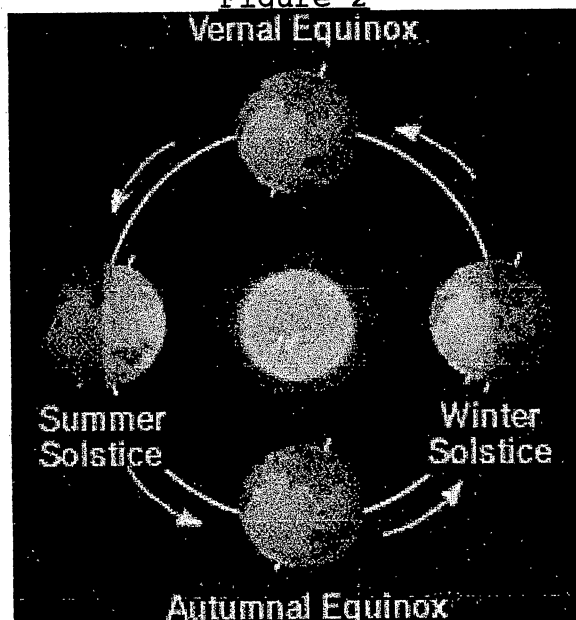
Figure 1



The Tilt of Earth's Axis

This angle of tilt remains constant, that is Earth always points in the same direction (towards Polaris, the North Star), and is what allows our seasons to be present. It does this by allowing varying degrees of sunlight to reach the Earth's surface at different points of its revolution about the Sun (the Earth revolves around the Sun approximately every 365 days) (Figure 2).

Figure 2
Vernal Equinox



When Earth is pointing towards the Sun, the Northern

When Earth is pointing towards the Sun, the Northern Hemisphere (or half of the earth) receives the most direct sunlight causing it to be summer in the Northern Hemisphere, and winter in the Southern Hemisphere. When Earth is pointing away from the Sun, the Southern Hemisphere receives the most direct sunlight. Thus it is then summer in the Southern Hemisphere, and winter in the Northern Hemisphere. These times of the year are when the Summer and Winter Solstices respectively occur in the Northern Hemisphere. The Summer Solstice is the longest day of the year, and the Winter Solstice is the shortest day of the year.

Halfway in between the Solstices, Earth is neither pointed directly towards or away from the Sun. At these times, both the Northern and Southern Hemispheres receive about the same amount and intensity of sunlight. These times of the year are when the Spring and Autumnal Equinoxes occur. The Equinoxes are when the day and night are equal.

Hemispheres and Quadrants

In order to help organize Earth for humans to find their way around, we have divided it into imaginary sections. The most basic of these is the hemisphere. A hemisphere is a half of a sphere (remember that Earth is a sphere). The northern half is called the Northern Hemisphere, and the southern half is called the Southern Hemisphere. These two hemispheres are separated by an imaginary line called the Equator. Earth can also be divided into the Eastern and Western Hemispheres, these are separated by the an imaginary line called the Prime Meridian. Refer to the key to student Handout #2, "Earth's Hemispheres," for a graphic example.

If you were to divide Earth using both the Equator and the Prime Meridian, you would end up with four imaginary pieces called quadrants. The quadrants are named by the two overlapping hemispheres they are constructed out of. Thus, we have the North-East, North-West, South-East, and South-West quadrants. Refer to the key to student Handout #3, "Earth's Quadrants," for a graphic example.

Latitude, Longitude, and Coordinates

Lines of latitude and longitude were developed in order for a person to find an exact location on a map or globe of the Earth's surface. Lines of latitude run horizontally, East to West (or West to East), and form complete circles around the earth. The lines of latitude are numbered in positive degrees, both North and South, starting with zero, until they reach 90° at the poles. The equator is a line of latitude, it equals 0° latitude and bisects the Earth into the Northern and Southern Hemispheres. Even though they run East to West, lines of latitude are labeled as North or South

depending upon which hemisphere they are in because they

divide the earth into North and South sections. Since the lines of latitude run parallel to the equator, they are also known as parallels. Refer to the student Handout #4, "Lines of Latitude," for a graphic example.

Lines of longitude run North and South, or vertically, and terminate at the poles. The Prime Meridian and the International Date Line are lines of longitude, and they separate the Eastern and Western hemispheres. All lines of longitude (also known as meridians) are labeled as East or West depending upon which hemisphere they are in. The lines of longitude are numbered in positive degrees, both East and West, from 0° , which is the Prime Meridian, to the International Date Line which is 180° . The lines of longitude are the lines which correspond with the time zones. Refer to the student Handout #5, "Lines of Longitude," for a graphic example.

On a map, we use lines of latitude and longitude together to give us the exact location of anything on Earth. Lines of latitude and longitude together form a grid. At each intersection of the lines, there is a set of numbers called a coordinate. Coordinates consist of the number of degrees of the line of latitude and the line of longitude that intersect at that point. The degrees for the lines of latitude (North or South) always come first, followed by the degrees for the lines of longitude (East or West). For example, the coordinate for the point at which the 34° North line of latitude and the 119° West line of longitude cross would be ($34^{\circ}\text{N}, 119^{\circ}\text{W}$). This coordinate is for a spot right off the coast of Los Angeles, California. It means that this spot is 34° North of the Equator, and 119° West of the Prime Meridian (or Greenwich, England). Refer to the student Handout #6, "Coordinates Give Us the Place of a Space," for a graphic example.

The X-38

The X-38 has been designed as a precursor to the future Crew Return Vehicle (CRV) for the International Space Station (ISS). The CRV will be used as an emergency return spacecraft for the ISS crew. To aid in this function, the X-38/CRV has no control stick but instead has complete automatic guidance. The crew can make some inputs if necessary, but the computers controlling the vehicle determine where to land. This eliminates the necessity of possibly injured crew members having to pilot the CRV from the ISS to an emergency landing site on Earth.

Several factors help the computers of the CRV choose a landing site. One of these is the position of the landing

site relative to where the ISS is in orbit when the CRV

launches from the ISS. This helps by providing the astronauts aboard with the swiftest route to a landing site prepared to accommodate the CRV and with medical facility availability.

In determining flight time to the landing site, it is important to know the time zone that the site is in as well. Other important factors include a need for calm weather, and disposal of the Deorbit Propulsion Stage (DPS). The X-38/CRV uses a DPS that is attached to the aft (rear) of the vehicle to perform the Deorbit Burn. The DPS is then jettisoned and burns up during reentry. The landing site must allow for the DPS landing "footprint" (anywhere it could possible land) to be in an unpopulated area (preferably the ocean).

Part 1

Materials and Tools:

- Globe
- Flashlight

Procedures:

1. Discuss with students the purpose of the X-38 and the CRV (See "The X-38" under Background Information).
2. Ask the students why they think day and night happen. Chart their answers.
3. Explain to the students that the day and night (diurnal) cycle is caused by Earth rotating about its own axis (See "The Diurnal Cycle" under Background Information).
4. Have one student hold the globe, and another student hold the flashlight. Explain that the globe represents the Earth, and the flashlight represents the Sun.
5. Turn the flashlight on. Discuss with the students that the side of the globe exposed to the light of the flashlight (Sun) would be currently experiencing daytime. The side of the globe that is hidden from the flashlight (Sun) would be currently in nighttime.
6. Have the student holding the globe slowly rotate (spin) the globe. Point out to the students that as the globe (Earth) spins, different parts of the globe (Earth) come into contact with the flashlight's (Sun's) rays. Those parts of the globe (Earth) are experiencing day, while the parts not exposed to the rays are in night.
7. Take the students outside (it should be a sunny day). Arrange the students in a circle with one student in the middle. Tell the students that the student in the middle is the "sun," and everyone else in the circle is a planet. Have the students first rotate; spin in a slow circle. Ask them to stop at day time (when they are facing the sun) and night time (when they are facing away). Have the students lean towards the sun slightly (to simulate Earth's tilt) then revolve around the "sun" (walk around the circle, always facing the sun). Now have the students revolve slowly as the rotate around the "sun." As they move around the circle they should be alternately facing towards and away from the "sun." Have the students stop at winter (when their heads are pointed out of the circle), summer (heads pointed in), and spring and fall (heads pointing towards and away from the direction of movement).

Part 2

Materials and Tools:

- "Earth's Time Zones" Handout #1 (Please see Management)
- Yarn
- Paper numbers from 1-24, and from 00:00-24:00 (printed on index cards)
- Globe
- Flashlight

Procedures:

1. Ask students if they think dawn occurs at the same time for everybody on the same side of the Earth. Review with students how and why dawn occurs at different times on different parts of the Earth. For example, when it was dawn here this morning, was it also dawn in New York? If necessary repeat the demonstrations in Part 1.
2. Discuss with students that because dawn occurs at different times, we have separated the Earth into time zones, so that everyone gets the same amount of daylight in their day. (See "Time Zones" under Background Information)
3. Distribute Handout #1, "Earth's Time Zones." Have students locate Greenwich, England. Using yarn, have the students copy the lines for the time zones. At the end of Part 2 is an Extension for more advanced students.
4. Distribute the paper numbers, 1-24, one to a student. Have the student with the number 1 stand in the middle of the room, they will represent the time zone for Greenwich, England. Have the students with the numbers 2-24 decide, from the map, where their time zone would be in relation to the Greenwich Time Zone. Have them stand to one side or the other of the "Greenwich Zone" to represent this. The order should be: 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 1(GMT), 2, 3, 4, 5, 6, 7, 8, 9, 10, 11. Have the students form a circle so that they can see that the numbers are really in order (remind students that the Earth is round and that the poster is only what we use to see all of the Earth at one time). Have the students notice what numbers are opposite in the circle, for example the 1 and the 13 should be opposite each other. Have the students stand back in a line, and place their number cards on the floor.
5. Distribute the numbers 00:00-24:00. Explain to the students why the X-38 uses a 24 hour clock (because the military and many foreign countries where it might land use it). Have the student with the 00:00 stand at GMT

- (1). Have the students with the numbers 01:00-24:00

stand next to the numbered cards representing the time zones that they think their numbers belong to. The order should be: 11:00, 12:00, 13:00, 14:00, 15:00, 16:00, 17:00, 18:00, 19:00, 20:00, 21:00, 22:00, 23:00, 24:00, 00:00, 01:00, 02:00, 03:00, 04:00, 05:00, 06:00, 07:00, 08:00, 09:00, 10:00. Have the students again stand in a circle. They should notice that the 00:00 is directly across from 12:00. Discuss with students that the 12:00 zone is where the International Date Line can be found.

Extension for step 3:

Instead of using Handout #1, students can construct their own time zones poster using Handout #7a-1. This one does not include the time zones, so you may want to use the key to Handout #7 as well.

Materials (per student or student group):

- complete set of copies of Handout #7a-1 (p 75-86)
- scissors
- tape or staples
- yarn
- copies of Handout #1 (optional)

Directions:

1. Direct the students to trim the time zone poster sections so that they will fit neatly together.
2. Assemble the poster by taping or stapling the sections together.
3. Using yarn, run a line through Greenwich, connecting point A on the top of the map to point a on the bottom. Have the students connect the other points to create the time zones on the map. (They may use Handout #1 as a key).

Part 3

Materials and Tools:

- "Earth's Hemispheres" Handout #2
- "Earth's Quadrants" Handout #3
- "Lines of Latitude" Handout #4
- "Lines of Longitude" Handout #5
- "Coordinates Give Us the Place of a Space" Handout #6
- Globe or map (accessible to each student)

Procedures:

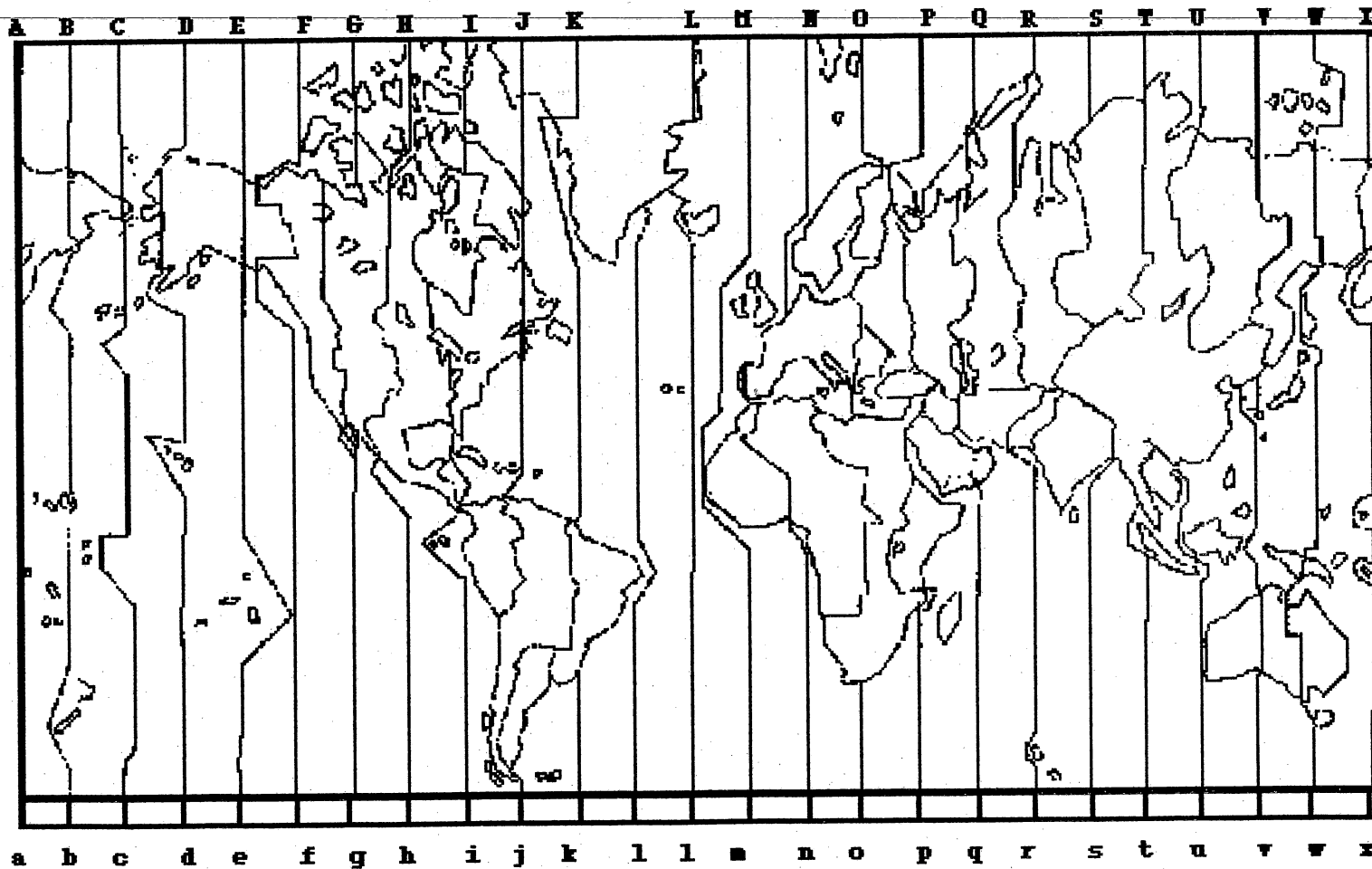
1. Ask students how they might find a place that they have never been to before. (Answer: using directions)
Review with students the four cardinal directions (you may wish to label the walls of your classroom accordingly, if they are not labeled already). Discuss how the X-38/CRV uses these directions too to find a good place to land in an emergency. (See "The X-38" in the Background Information)
2. Distribute the "Earth's Hemispheres" Handout (#2).
Discuss with students that the Earth can be divided into Northern and Southern Hemispheres, divided by the Equator. The Earth can also be divided into Eastern and Western Hemispheres, divided by the Prime Meridian.
Have the students complete Handout #2.
3. Distribute the "Earth's Quadrants" Handout (#3).
Discuss with students, that if you combine the four hemispheres, they produce four imaginary sections, or quadrants (see "Hemispheres and Quadrants" in the Background Information). These quadrants are what give us minor directions of the compass rose: North-East (NE), North-West (NW), South-East (SE), and South-West (SW) (the major directions are simply North, South, East, and West). Have the students complete Handout #3.
4. Ask students if they think that they could find a place they were looking for (like Disneyland or their home) knowing only which quadrant it was in. (Answer: No. There are many places in each quadrant.) Discuss that humans have put more imaginary lines on the Earth besides the Equator and the Prime Meridian. These lines are called lines of latitude (parallels) and lines of longitude (meridians).
5. Discuss with students that the lines that run horizontally (from East to West) are lines of latitude. The Equator is a line of latitude, and represents 0° (zero degrees) latitude. The lines of latitude are labeled either North or South depending on which hemisphere they are in, and they are numbered starting

at the equator (0°) to 180° . (See "Latitude and Longitude" in the Background Information) Distribute

Longitude" in the Background Information) Distribute the "Lines of Latitude" Handout (#4), and discuss the top half of the worksheet with the students. Have the students complete the bottom half with the aid of a globe or map. *If your resources do not have the places on this worksheet, before the lesson find a place nearby that is shown. Have the students then approximate their answers.

6. Discuss with students that the lines that run vertically (from North to South) are lines of longitude. The Prime Meridian is a line of longitude, and represents $0^{\circ}/360^{\circ}$ longitude. The lines of longitude are labeled either East or West depending on which hemisphere they are in, and they are numbered starting at the Prime Meridian (0°) all the way around the earth, back to the Prime Meridian (which would then represent 360°). (See "Latitude and Longitude" in the Background Information) Distribute the "Lines of Longitude" Handout (#5), and discuss the top half of the worksheet with the students. Have the students complete the bottom half with the aid of a globe or map. *If your resources do not have the places on this worksheet, before the lesson find a place nearby that is shown. Have the students then approximate their answers.
7. Discuss with students that the lines of latitude and longitude are labeled in degrees. Therefore each point where a line of latitude crosses a line of longitude gives us a set of degrees called coordinates. Each place on Earth has a set of coordinates different from any place else on Earth. Hand out the "Coordinates Give Us the Place of a Space" Handout, #7. Have the students complete the worksheet. They will need to use the latitude (#4) and longitude (#5) worksheets to assist.

Earth's Time Zones Handout #1

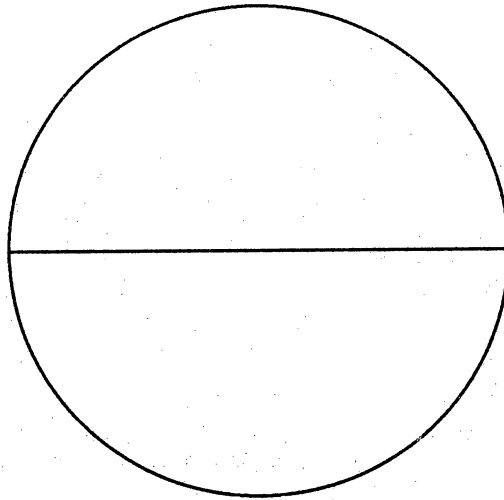


Name _____

Earth's Hemispheres Handout #2

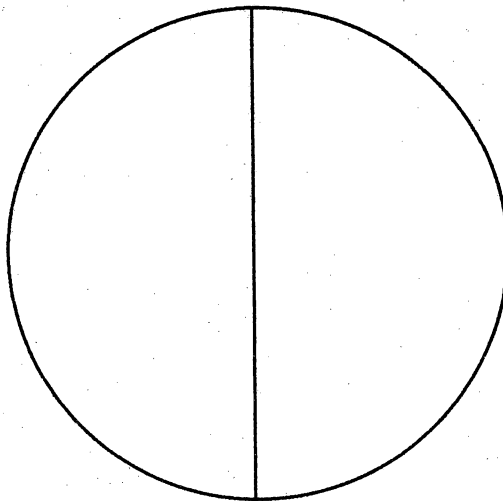
The **Equator** is a line of longitude. It separates the Northern Hemisphere from the Southern Hemisphere.

1. Label the horizontal line below "Equator."
2. Label the halves (hemispheres) "Northern Hemisphere" or "Southern Hemisphere." (Hint: Think of the compass rose)



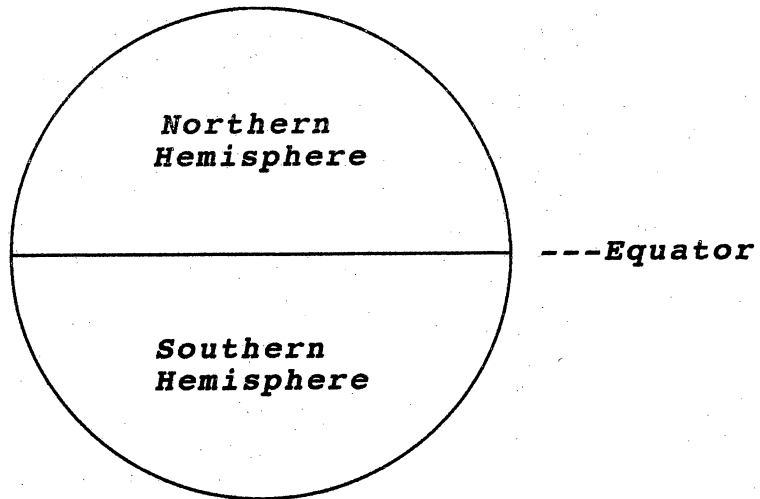
The **Prime Meridian** is a line of latitude. It separates the Eastern Hemisphere from the Western Hemisphere.

1. Label the vertical line below "Prime Meridian."
2. Label the halves (hemispheres) "Eastern Hemisphere" or "Western Hemisphere."

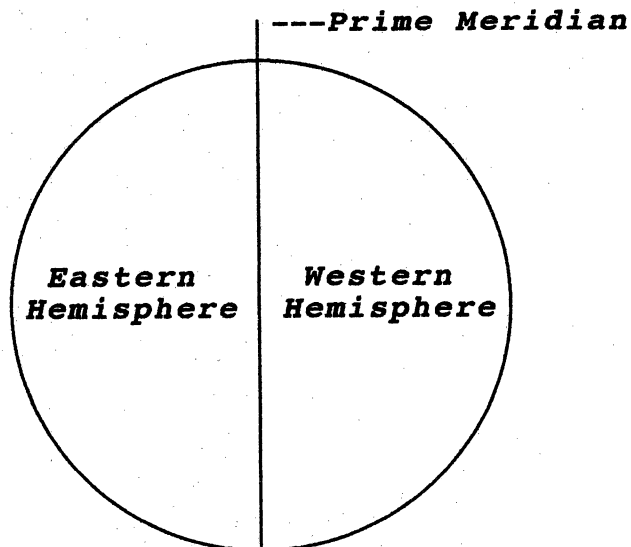


Earth's Hemispheres
Handout #2--KEY

The **Equator** is a line of longitude. It separates the Northern Hemisphere from the Southern Hemisphere.



The **Prime Meridian** is a line of latitude. It separates the Eastern Hemisphere from the Western Hemisphere.



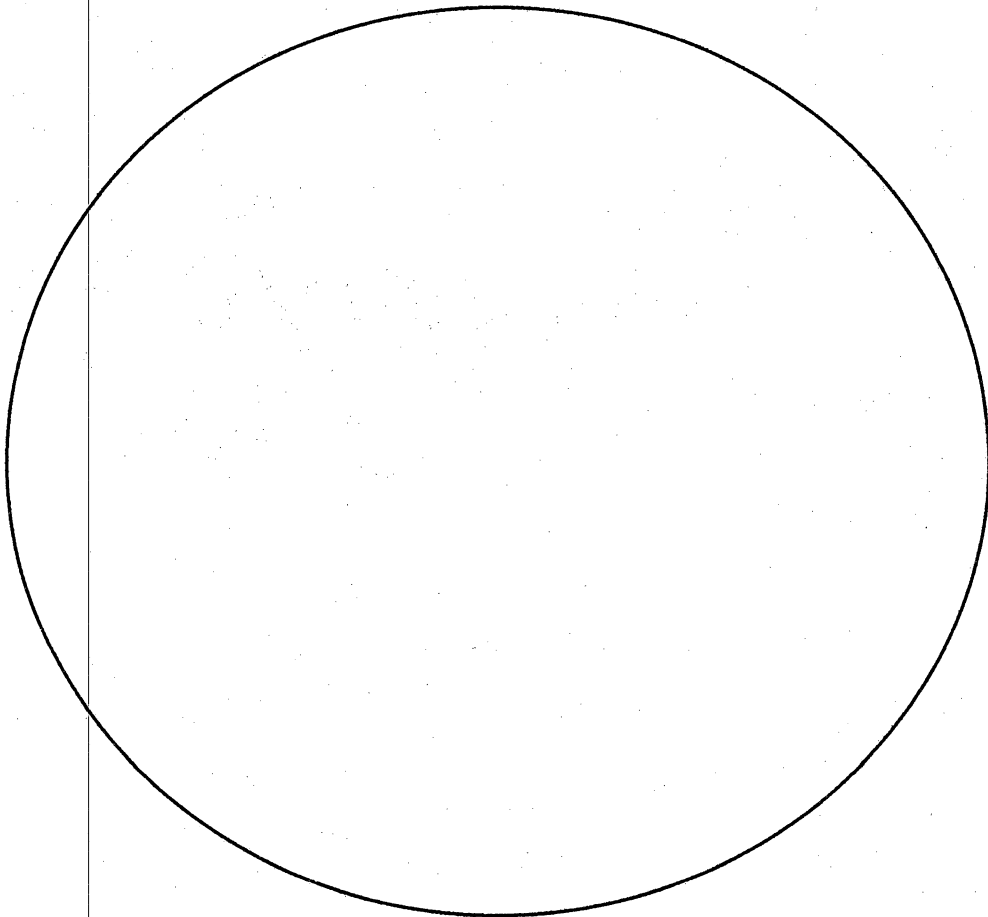
Name _____

Earth's Quadrants Handout #3

Earth's four hemispheres can be combined to "create" four imaginary sections of the Earth (quadrants). Each quadrant is labeled by both of the hemispheres that it encompasses.

Directions:

1. Draw and label the Equator to show the Northern and Southern Hemispheres.
2. Draw and label the Prime Meridian to show the Eastern and Western Hemispheres.
3. Label each quadrant with both of the names of the hemispheres that it intersects, always putting "South" or "North" before "East" or "West".

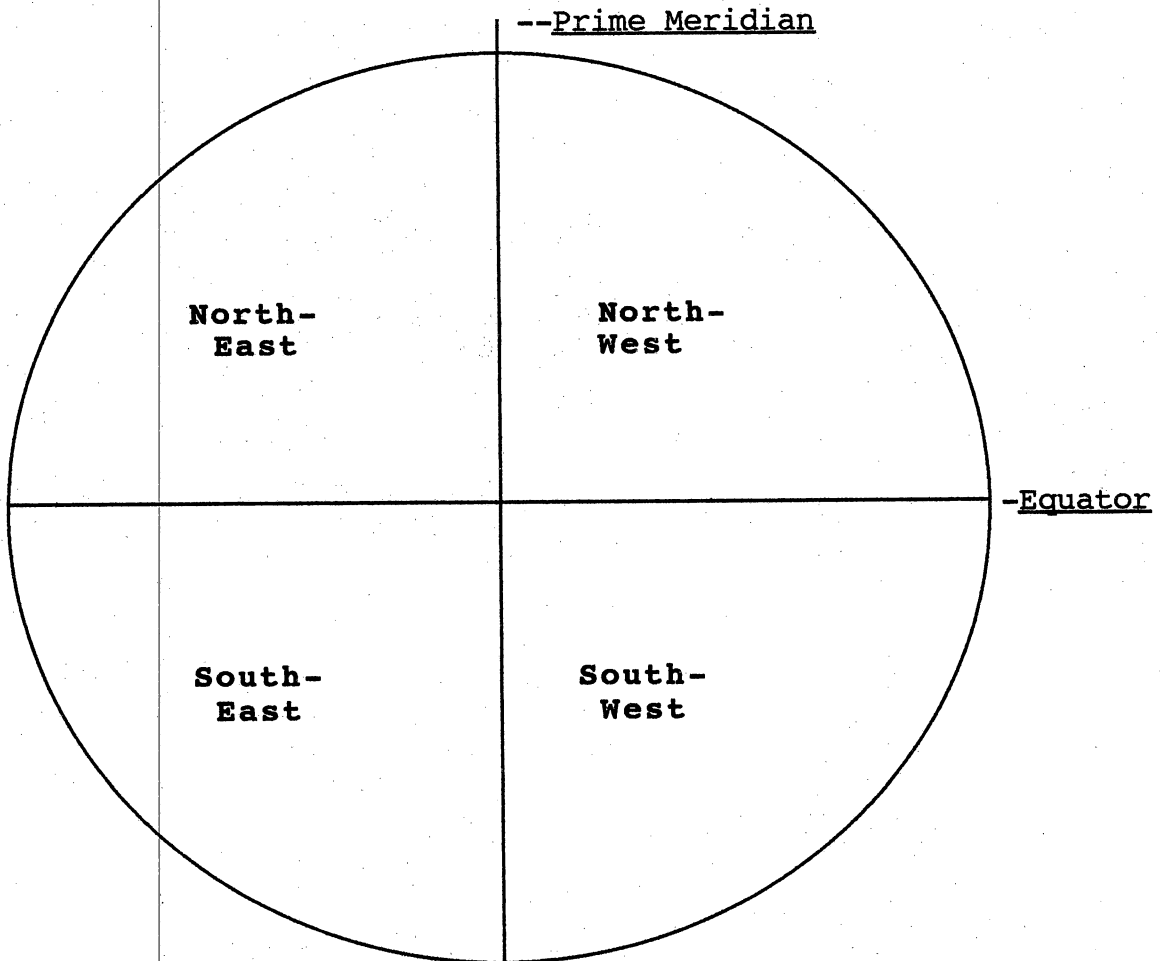


Earth's Quadrants
Handout #3--KEY

Earth's four hemispheres can be combined to "create" four imaginary sections of the Earth (quadrants). Each quadrant is labeled by both of the hemispheres that it encompasses.

Directions:

1. Draw and label the Equator to show the Northern and Southern Hemispheres.
2. Draw and label the Prime Meridian to show the Eastern and Western Hemispheres.
3. Label each quadrant with both of the names of the hemispheres that it intersects, always putting "South" or "North" before "East" or "West".

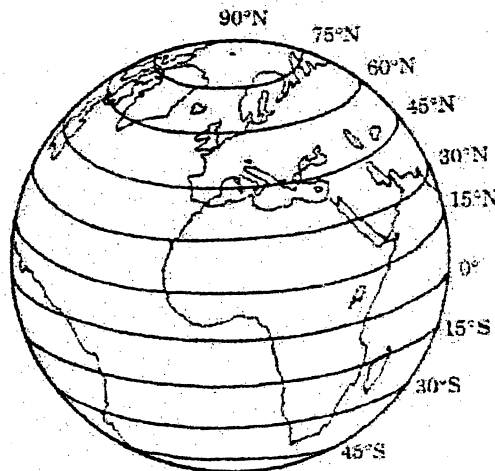


Name _____

Lines of Latitude Handout #4

Lines of Latitude can help us find a certain place. The lines that go around the globe from East to West are called lines of latitude. Since these lines run parallel to the equator (which is also a line of latitude) they are also called parallels. Do you want to know how far North or South you are? Lines of latitude can show you!

Starting from the equator, which is 0° latitude, each line of latitude is labeled in degrees. All lines of latitude to the North of the equator (in the Northern Hemisphere) are labeled N for North. All lines of latitude to the South of the equator (in the Southern Hemisphere) are labeled S for South. So even though the lines of latitude run East and West, they really tell us how far North or South we are. (Hint: to help remember latitude, think flat--lines of latitude lie flat)



Use a globe or a map to find the latitude for each of the following potential landing sites for the X-38/CRV. Don't forget to label each one with the number of degrees and whether it is North or South.

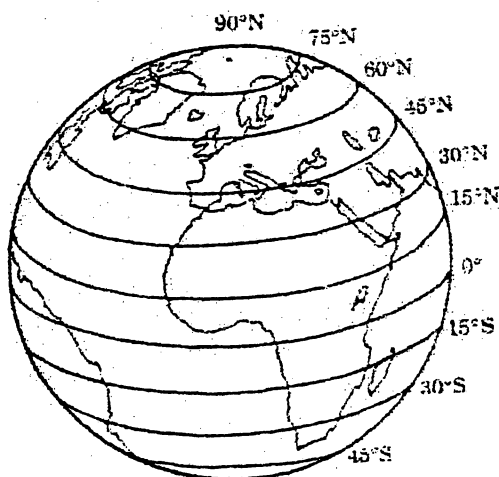
1. Bonneville, Utah, U.S.A. _____
2. Coober-Pedy, Australia _____
3. Captieux, France _____
4. Kalahari, Botswana _____
5. Resistencia, Argentina _____
6. Baja California, Mexico _____
7. Edwards Air Force Base, California, U.S.A. _____

Lines of Latitude

Handout #4--KEY

Lines of Latitude can help us find a certain place. The lines that go around the globe from East to West are called lines of latitude. Since these lines run parallel to the equator (which is also a line of latitude) they are also called parallels. Do you want to know how far North or South you are? Lines of latitude can show you!

Starting from the equator, which is 0° latitude, each line of latitude is labeled in degrees. All lines of latitude to the North of the equator (in the Northern Hemisphere) are labeled N for North. All lines of latitude to the South of the equator (in the Southern Hemisphere) are labeled S for South. So even though the lines of latitude run East and West, they really tell us how far North or South we are. (Hint: to help remember latitude, think flat--lines of latitude lie flat)



Use a globe or a map to find the latitude for each of the following potential landing sites for the X-38/CRV. Don't forget to label each one with the number of degrees and whether it is North or South. (All numbers are approximate)

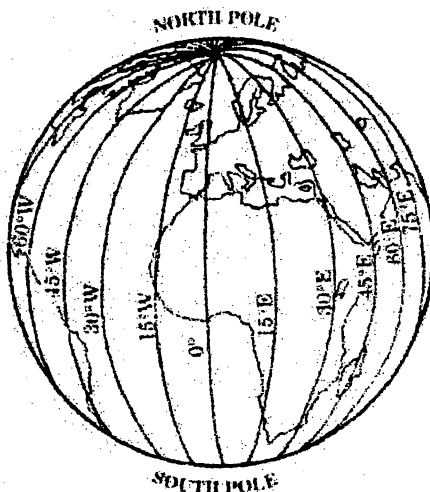
1. Bonneville, Utah, U.S.A. 40°N
2. Coober-Pedy, Australia 29°S
3. Captieux, France 44°N
4. Kalahari, Botswana 23°S
5. Resistencia, Argentina 24°S
6. Baja California, Mexico 30°N
7. Edwards Air Force Base, California, U.S.A. 34°N

Name _____

Lines of Longitude Handout #5

Lines of Longitude can help us find a certain place. The lines that go around the globe from North to South are called lines of longitude. Since these lines run parallel to the prime meridian (which is also a line of longitude) they are also called meridians. Do you want to know how far East or West you are? Lines of longitude can show you!

Starting from the prime meridian, which is 0° longitude, each line of longitude is labeled in degrees. All lines of longitude to the East of the prime meridian (in the Eastern Hemisphere) are labeled E for East. All lines of longitude to the West of the prime meridian (in the Western Hemisphere) are labeled W for West. So even though the lines of longitude run North and South, they really tell us how far East or West we are. (Hint: to help remember longitude, think long--lines of latitude go a long way up)



Use a globe or a map to find the longitude for each of the following potential landing sites for the X-38/CRV. Don't forget to label each one with the number of degrees and whether it is East or West.

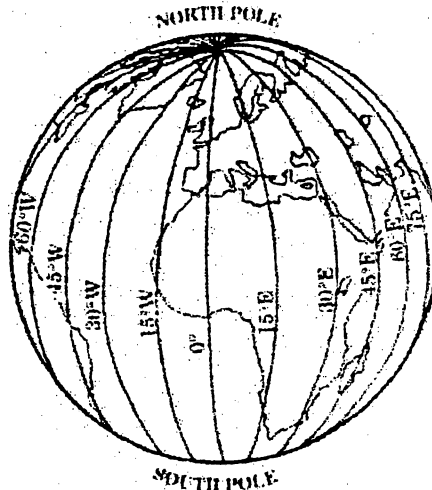
1. Bonneville, Utah, U.S.A. _____
2. Coober-Pedy, Australia _____
3. Captieux, France _____
4. Kalahari, Botswana _____
5. Resistencia, Argentina _____
6. Baja California, Mexico _____
7. Edwards Air Force Base, California, U.S.A. _____

Lines of Longitude

Handout #5--KEY

Lines of Longitude can help us find a certain place. The lines that go around the globe from North to South are called lines of longitude. Since these lines run parallel to the prime meridian (which is also a line of longitude) they are also called meridians. Do you want to know how far East or West you are? Lines of longitude can show you!

Starting from the prime meridian, which is 0° longitude, each line of longitude is labeled in degrees. All lines of longitude to the East of the prime meridian (in the Eastern Hemisphere) are labeled E for East. All lines of longitude to the West of the prime meridian (in the Western Hemisphere) are labeled W for West. So even though the lines of longitude run North and South, they really tell us how far East or West we are. (Hint: to help remember longitude, think long--lines of latitude go a long way up)



Use a globe or a map to find the longitude for each of the following potential landing sites for the X-38/CRV. Don't forget to label each one with the number of degrees and whether it is East or West. (All numbers are approximate)

1. Bonneville, Utah, U.S.A. 112°W
2. Coober-Pedy, Australia 134°E
3. Captieux, France 0°
4. Kalahari, Botswana 22°E
5. Resistencia, Argentina 63°W
6. Baja California, Mexico 118°W
7. Edwards Air Force Base, California, U.S.A. 117°W

Name _____

**Coordinates Give Us the Place
of a Space!
Handout #6**

We have now worked with lines of latitude and lines of longitude. These lines can give us a general idea of where we are on Earth. If we want to know exactly where we are, we need to use lines of latitude and longitude together. When we put lines of latitude and longitude together they form a grid. Where each line crosses there is a set of numbers called a coordinate. Coordinates are made up of the number of degrees of the line of latitude and the line of longitude that cross at that point. The degrees for the lines of latitude (North or South) always come first, followed by the degrees for the lines of longitude (East or West). For example the coordinates for Edwards Air Force Base, California are ($34^{\circ}\text{N}, 117^{\circ}\text{W}$). This means that Edwards Air Force Base is 34 degrees North of the Equator, and 117 degrees West of the Prime Meridian.

A. Using the handouts "Lines of Latitude" and "Lines of Longitude," fill in the coordinates for the potential landing sites for the X-38/CRV. The first one has been done for you.

1. Edwards Air Force Base, California, U.S.A. ($34^{\circ}\text{N}, 117^{\circ}\text{W}$)
2. Bonneville, Utah, U.S.A. _____
3. Coober-Pedy, Australia _____
4. Captieux, France _____
5. Kalahari, Botswana _____
6. Resistencia, Argentina _____
7. Baja California, Mexico _____

B. For extra practice, use a map of the world to find a set of coordinates for the countries in 1-3. For 4-6 find the country that is at the coordinates listed.

1. Italy _____
2. United Kingdom _____
3. South Africa _____
4. ($40^{\circ}\text{N}, 5^{\circ}\text{W}$) _____
5. ($15^{\circ}\text{N}, 100^{\circ}\text{E}$) _____
6. ($20^{\circ}\text{S}, 135^{\circ}\text{E}$) _____

**Coordinates Give Us the Place
of a Space!
Handout #6--KEY**

We have now worked with lines of latitude and lines of longitude. These lines can give us a general idea of where we are on Earth. If we want to know exactly where we are, we need to use lines of latitude and longitude together. When we put lines of latitude and longitude together they form a grid. Where each line crosses there is a set of numbers called a coordinate. Coordinates are made up of the number of degrees of the line of latitude and the line of longitude that cross at that point. The degrees for the lines of latitude (North or South) always come first, followed by the degrees for the lines of longitude (East or West). For example the coordinates for Edwards Air Force Base, California are ($34^{\circ}\text{N}, 117^{\circ}\text{W}$). This means that Edwards Air Force Base is 34 degrees North of the Equator, and 117 degrees West of the Prime Meridian.

A. Using the handouts "Lines of Latitude" and "Lines of Longitude," fill in the coordinates for the potential landing sites for the X-38/CRV. The first one has been done for you.

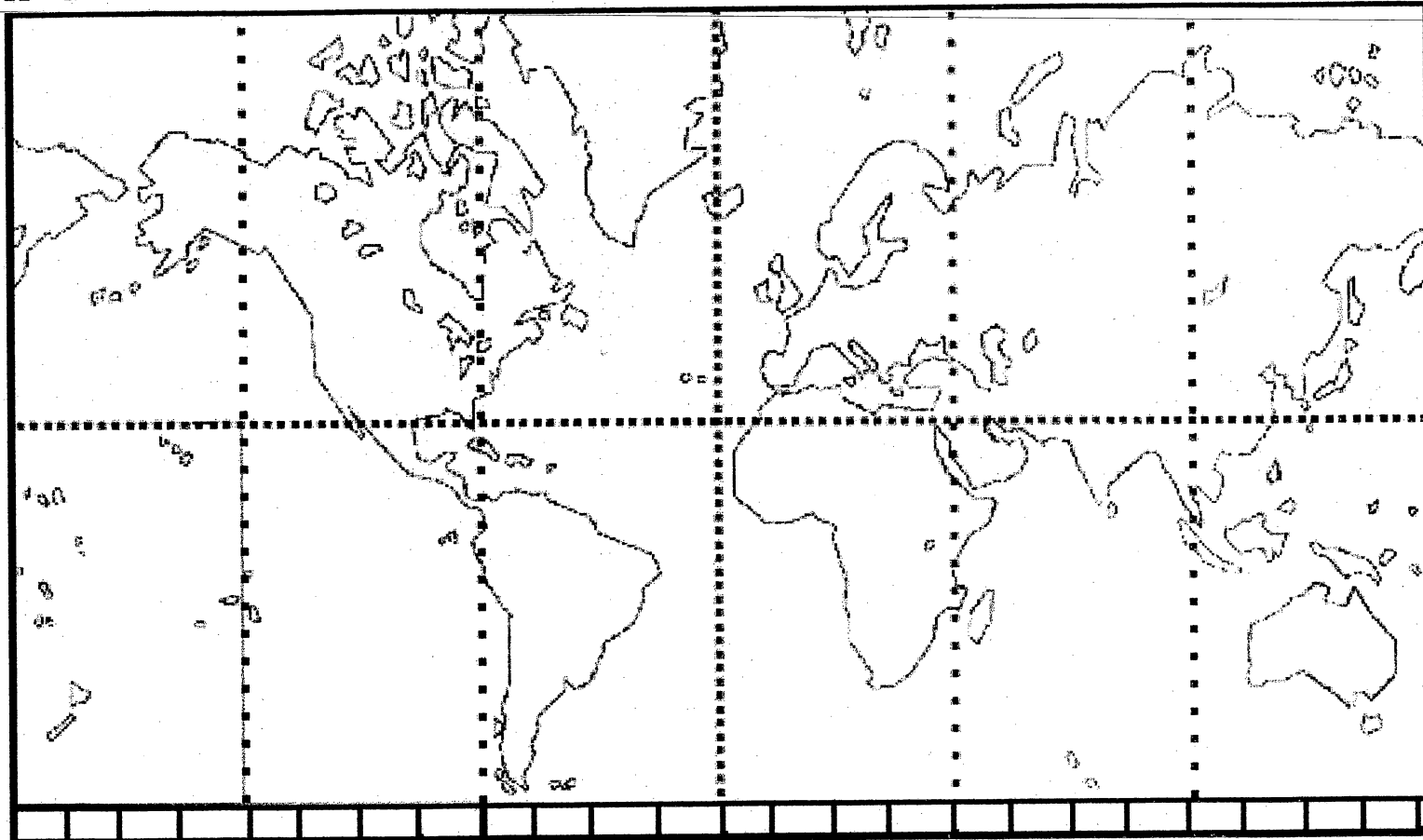
1. Edwards Air Force Base, California, U.S.A. ($34^{\circ}\text{N}, 117^{\circ}\text{W}$)
2. Bonneville, Utah, U.S.A. ($40^{\circ}\text{N}, 112^{\circ}\text{W}$)
3. Coober-Pedy, Australia ($29^{\circ}\text{S}, 134^{\circ}\text{E}$)
4. Captieux, France ($44^{\circ}\text{N}, 0^{\circ}$)
5. Kalahari, Botswana ($23^{\circ}\text{S}, 22^{\circ}\text{E}$)
6. Resistencia, Argentina ($24^{\circ}\text{S}, 63^{\circ}\text{W}$)
7. Baja California, Mexico ($30^{\circ}\text{N}, 118^{\circ}\text{W}$)

B. For extra practice, use a map of the world to find a set of coordinates for the countries in 1-3. For 4-6 find the country that is at the coordinates listed.

1. Italy **suggested:** ($42^{\circ}\text{N}, 14^{\circ}\text{E}$)
2. United Kingdom **suggested:** ($52^{\circ}\text{N}, 0^{\circ}$)
3. South Africa **suggested:** ($30^{\circ}\text{S}, 25^{\circ}\text{E}$)
4. ($40^{\circ}\text{N}, 5^{\circ}\text{W}$) **Spain**
5. ($15^{\circ}\text{N}, 100^{\circ}\text{E}$) **Thailand**
6. ($20^{\circ}\text{S}, 135^{\circ}\text{E}$) **Australia**

Handout #7--KEY

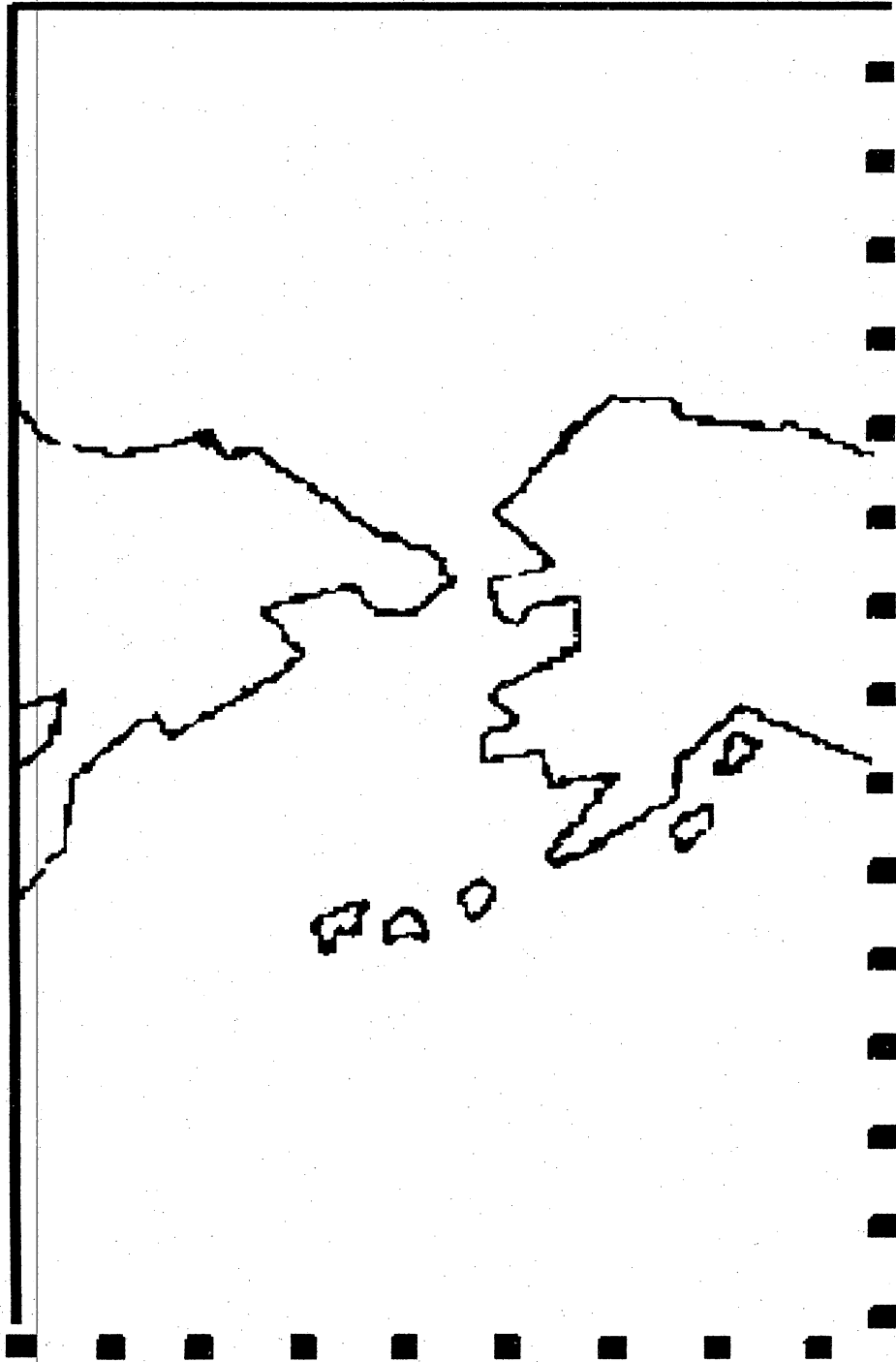
A B C D E F G H I J K L M N O P Q R S T U V W X



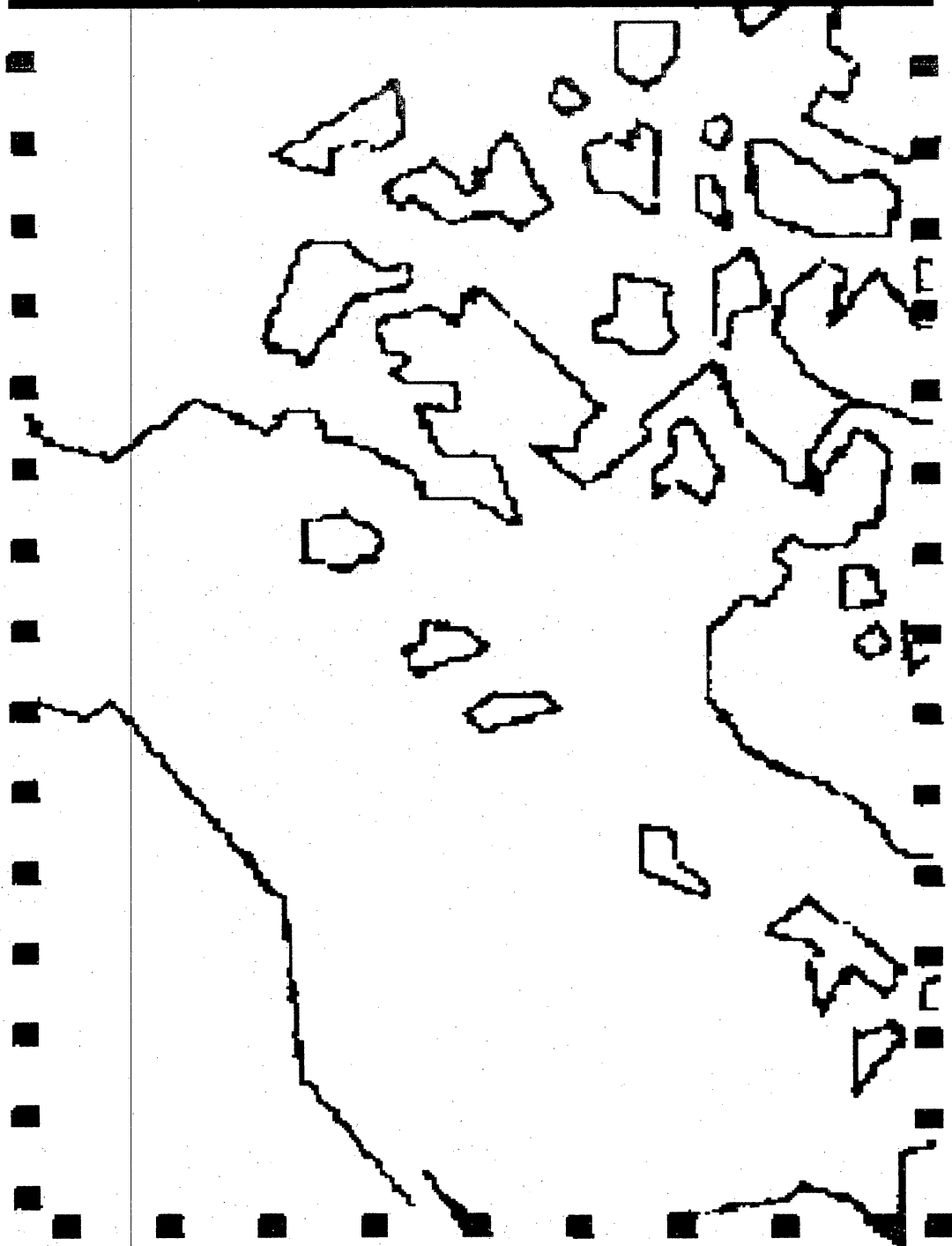
a b c d e f g h i j k l m n o p q r s t u v w x

Handout #7a

A B C D

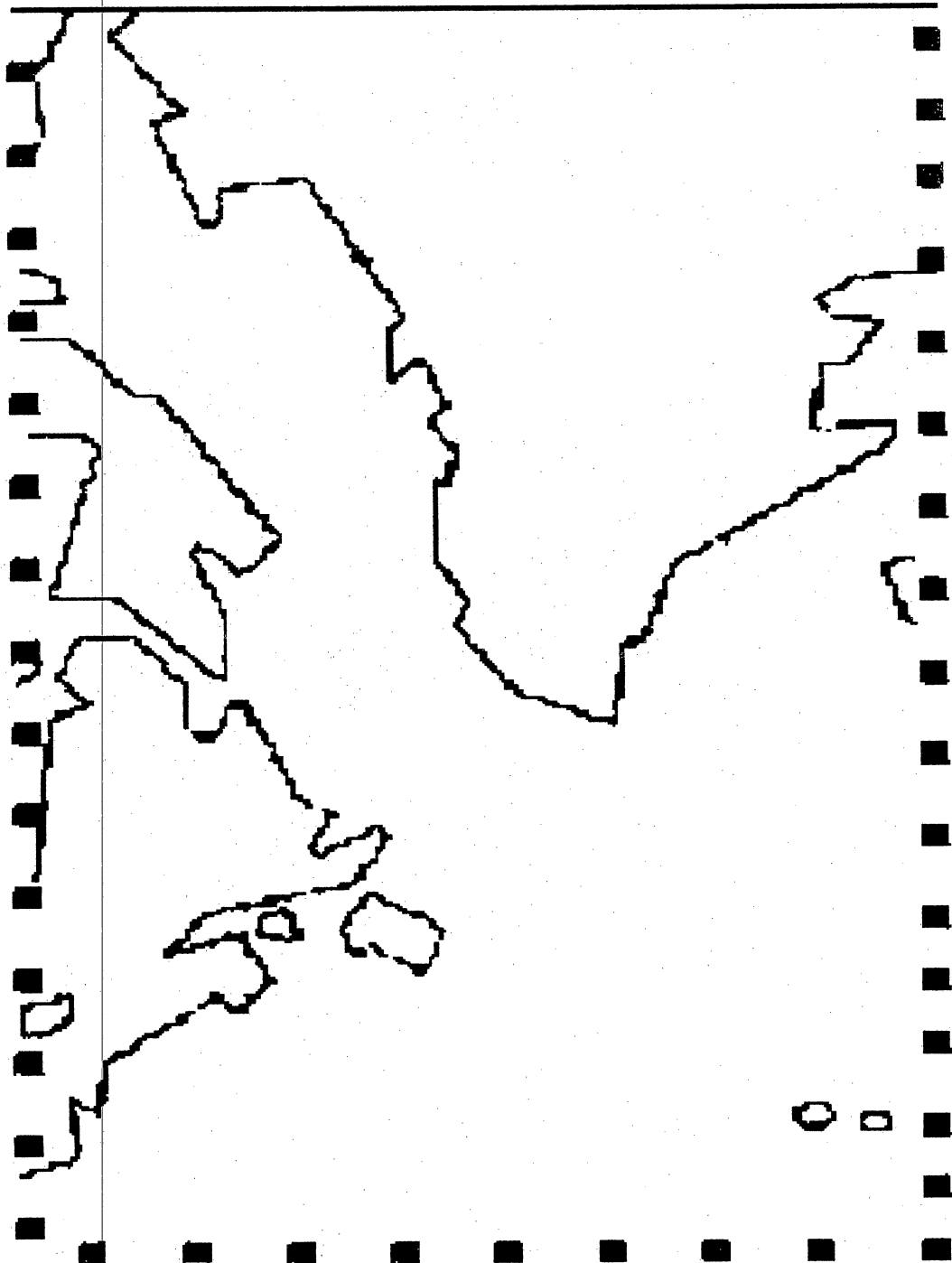


E F G H

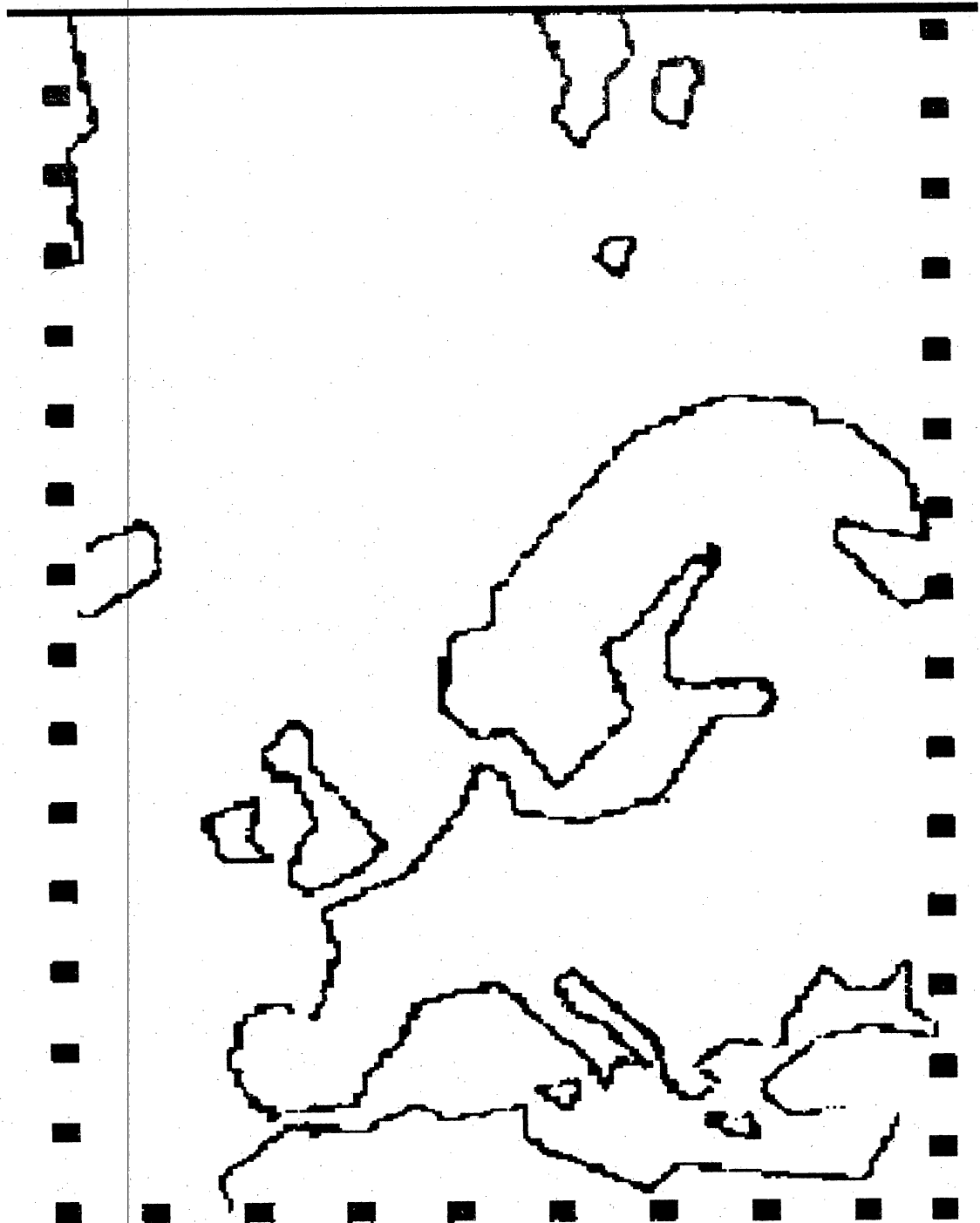


Handout #7c

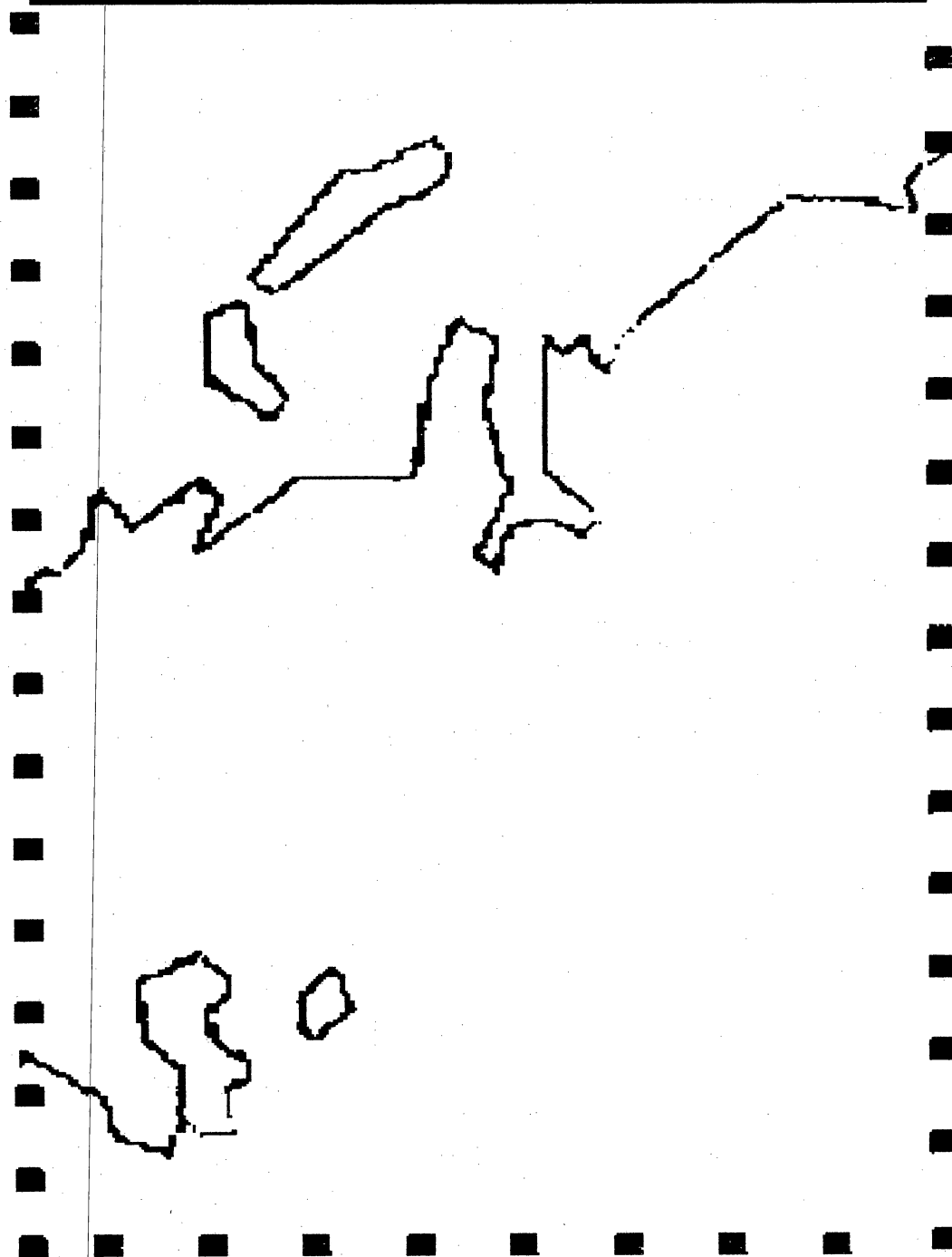
I J K L



M N O P

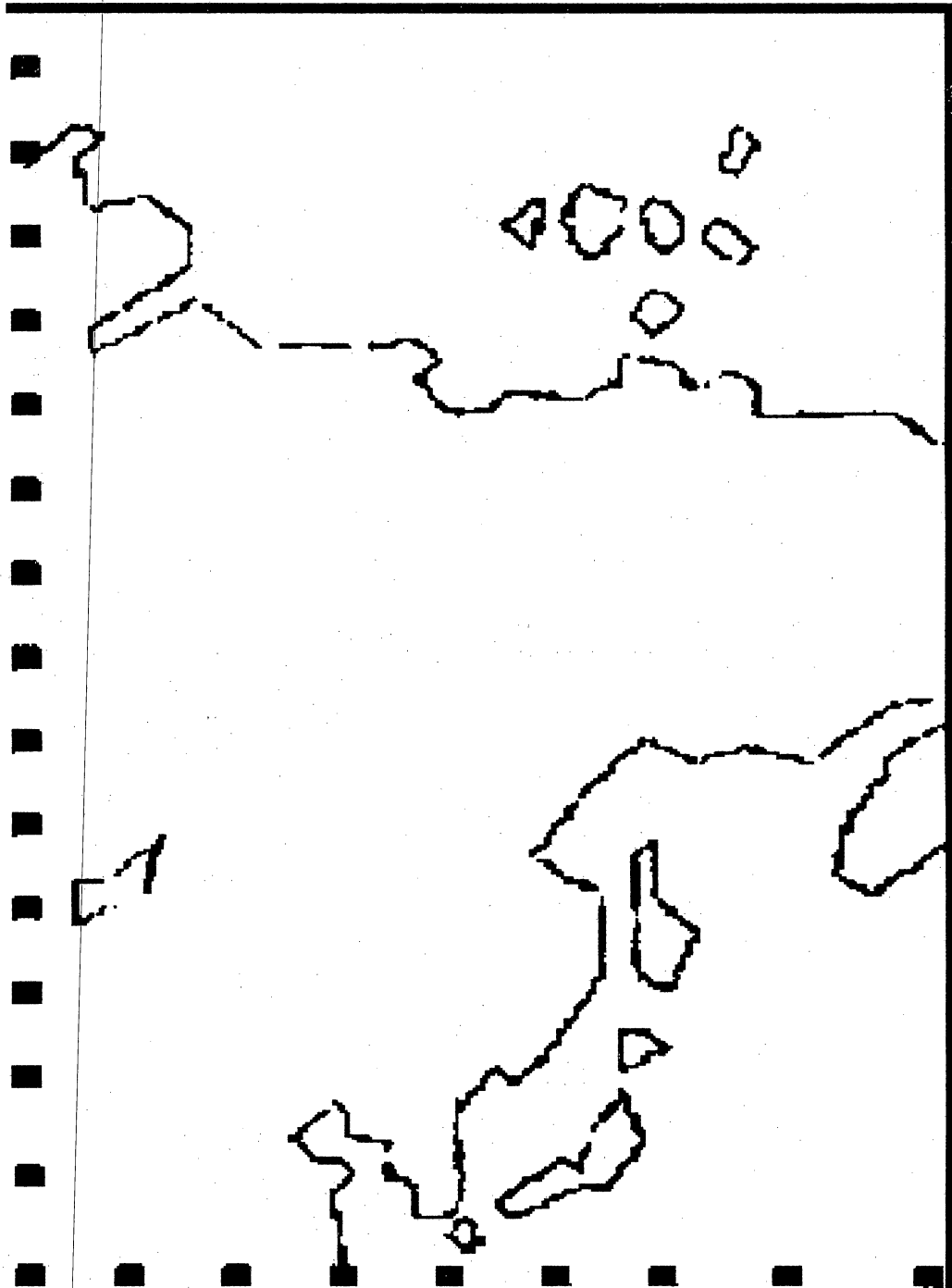


Q R S T

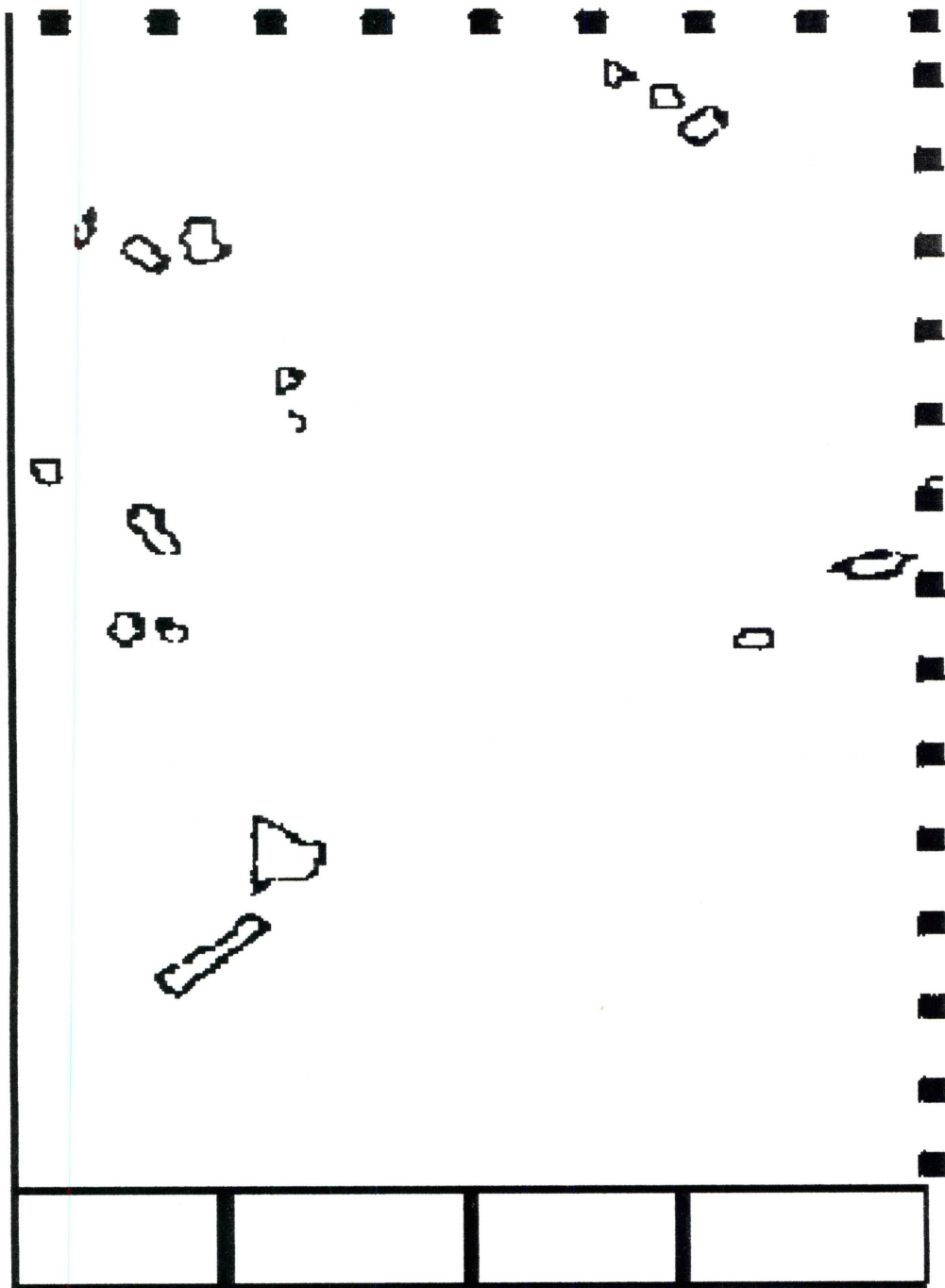


Handout #7f

U V W X

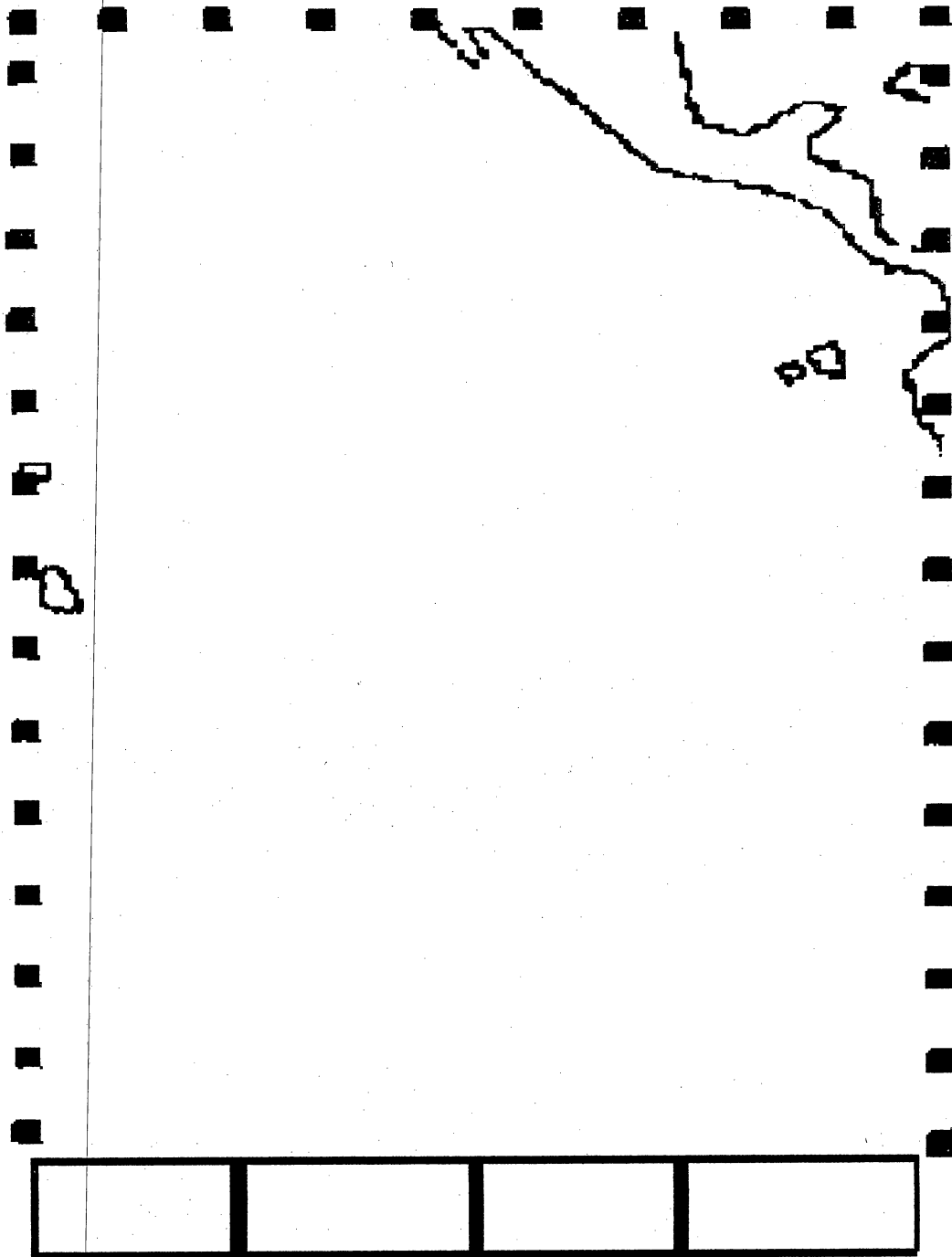


Handout #7g



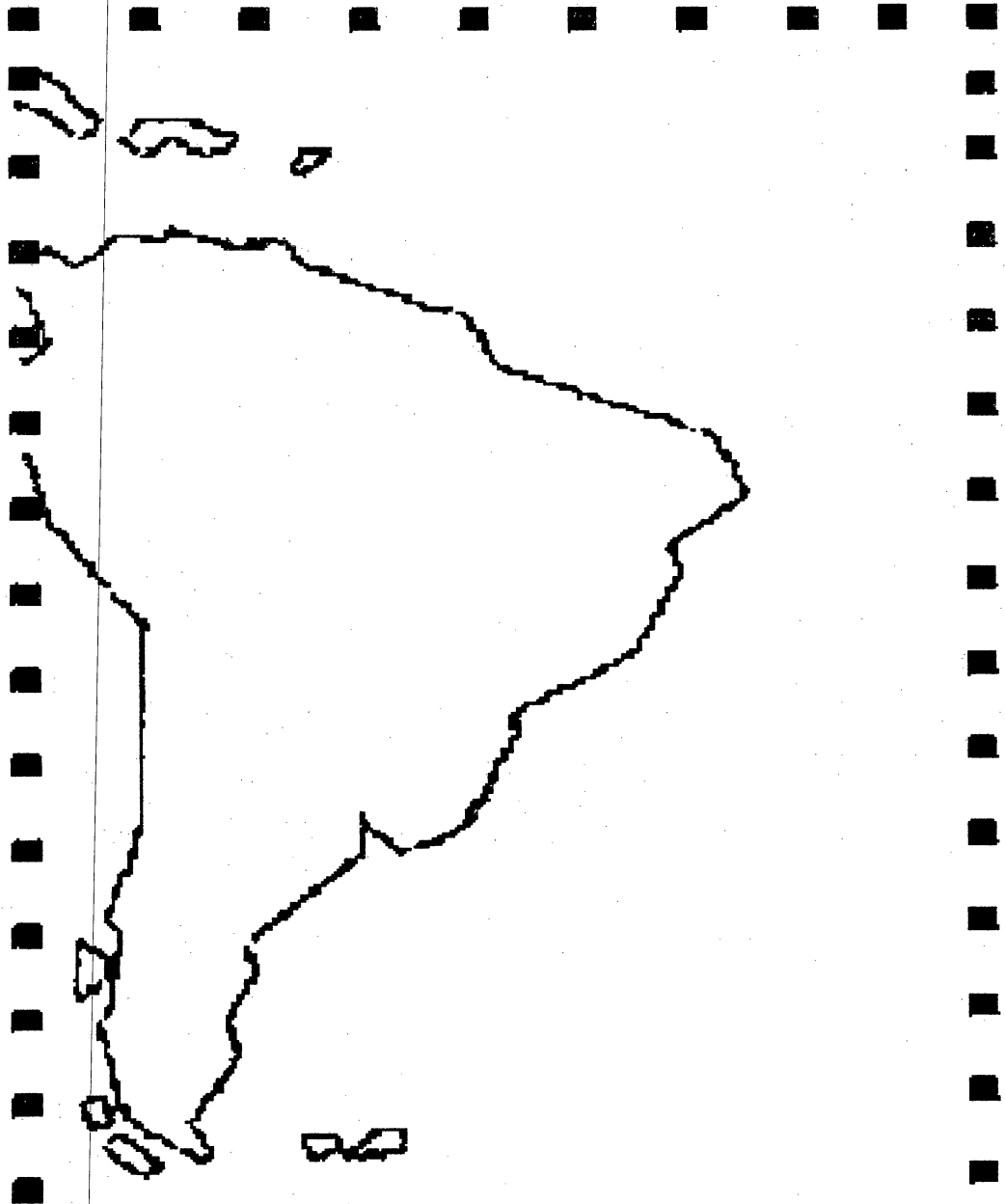
a b c d

Handout #7h



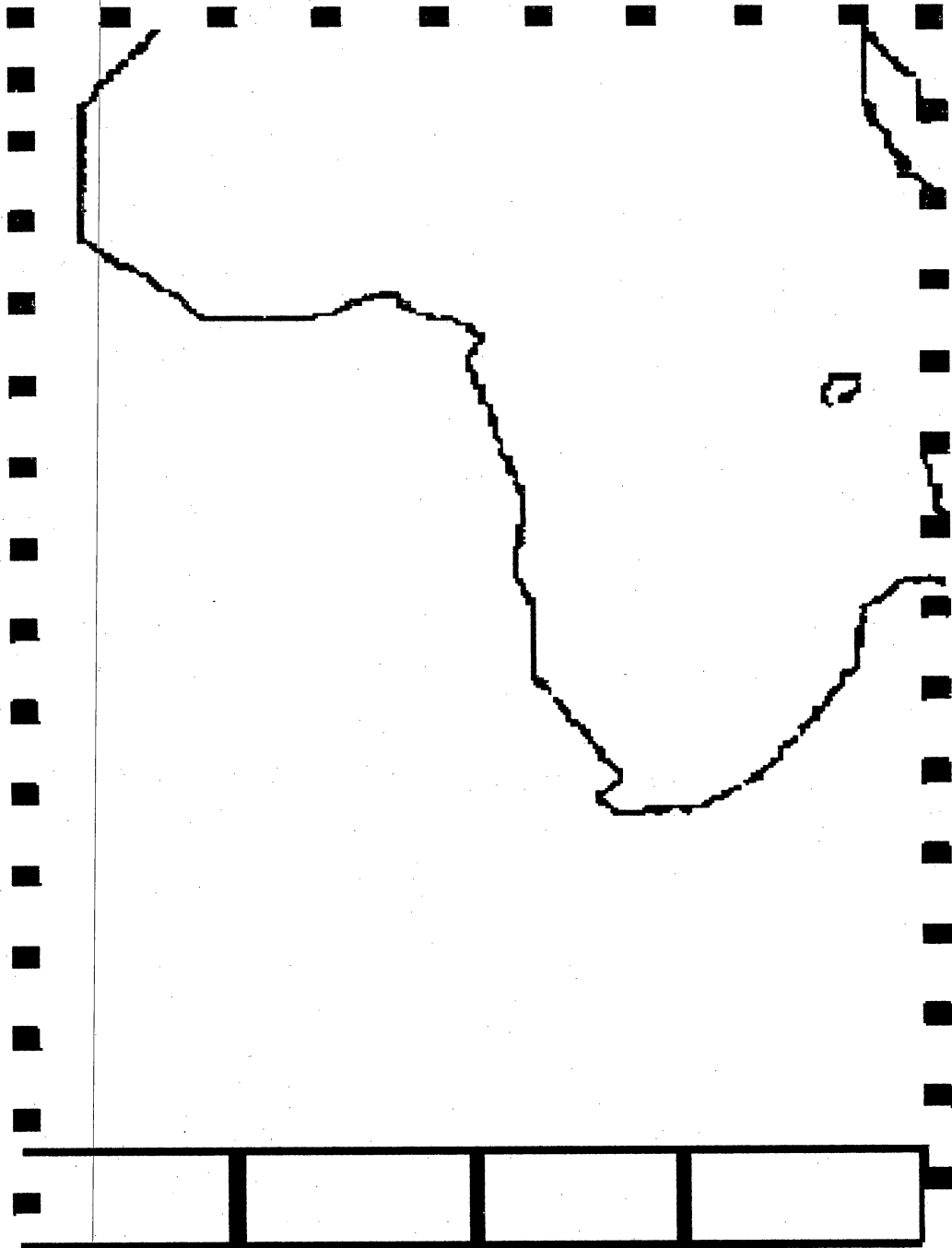
e f g h

Handout #7i



i j k l l

Handout #7j



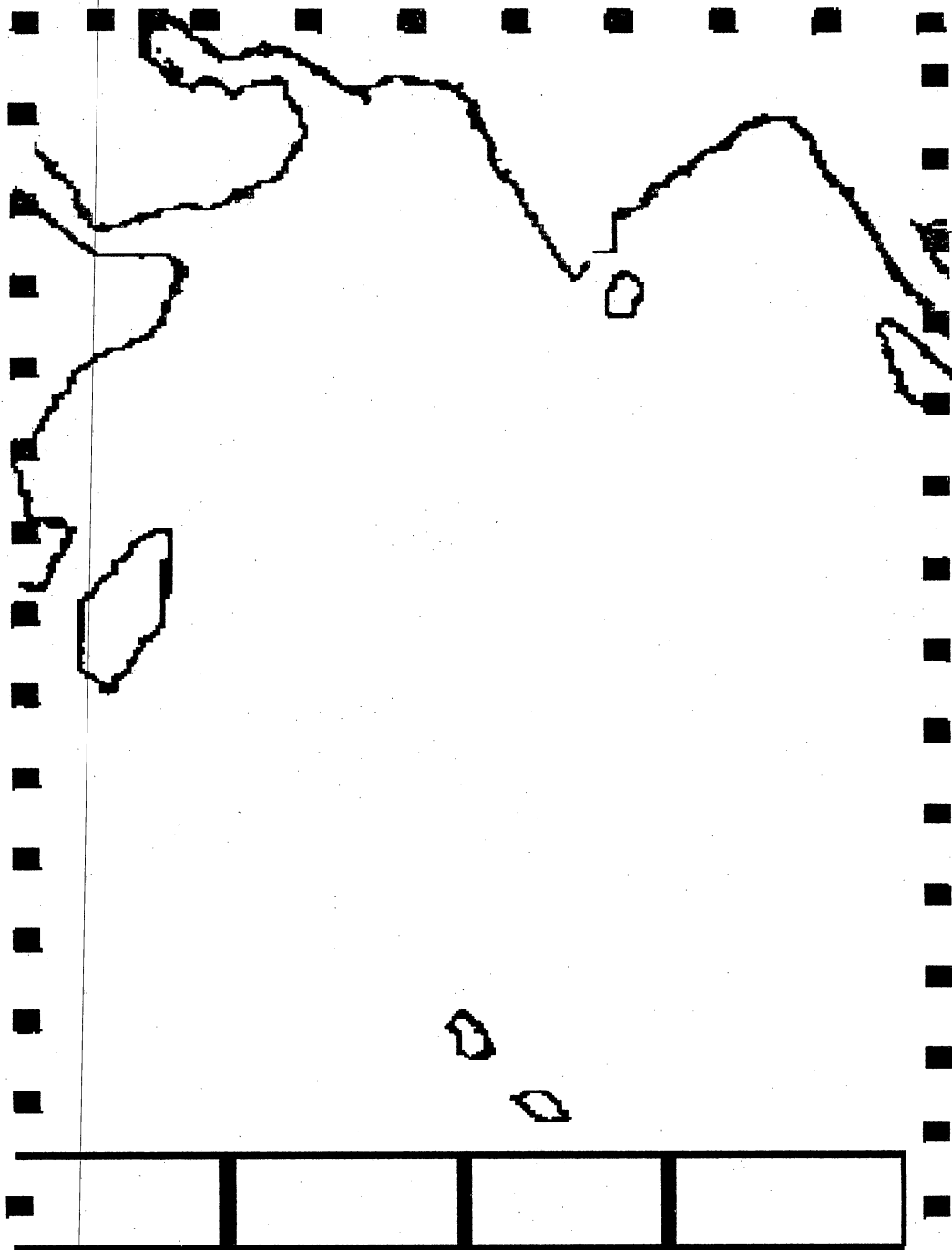
m

n

o

p

Handout #7k



q

r

s

t

Handout #71



u

v

w

x

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